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History of Science and Technology in India

Edited by

G Kuppuram • K Kumudamani

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About the Book

History of Science and Technology in India is the product of the heartiest cooperation between the Editors and Publishers. This book is devoted solely to scientific subjects. It has highlighted the Astronomical, Technological Geological, Medical, Industrial, Developments in the ancient, medieval and modern India.

The Authors whose essays have been compiled in this book need no introduction as they are well-known in their respective fields of their original researches. Their contribution make it clear that this country though better known for its spiritual greatness, witnessed alsc a high standard of scientific achievements in various fields.

Medical science developed in India about the beginning of the Christian era. One of the well-known authorities on Indian medicine was Charaka, who is said to have flourished during the Kushana ruler Kanishka.

Mathematics are dealt with in special chapters of the books on the early Indian astronomers. India attained excellence in Algebra. The earliest works of successful Indian Astronomy were the form treatisers called the Siddantas. Aryabhatta who was born at Patliputra in 476 A.D. reduced the doctrines of early works on Astronomy and Mathematics to a practical or concised form.

The earliest coinage of India is known as Punch-marked coins ranging in date from C. 6th Century B.C to 3rd Century B.C. They were mostly of silver. The bent-bar coins from Taxila form a destined class of Punch-marked coins.

The Kushana rulers issued a large number of gold coins some of which bear kharoshti inscriptions. Kushanas were eclectic in outlook and their coins bear various Greek, Zorostrians and Indian deities.

The History of Indian metal-casting goes back to the days of the Indus Civilization. The dancing girl from Mohanjodaro is an excellent piece of metal work. Some of the bronzes of the Gupta, Pallava, Pala and Chola period are among the first specimens of Indian Art.

Various types of technology during the Indus valley civilization, in the classical Age of India, the textile tools used in making the Ajanta Sculptures and Mughal Painting, the Fire Arms, have been very lucidly described.

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HISTORY OF SCIENCE AND TECHNOLOGY IN INDIA

History of Science and Technology in India

(in 12 Volumes)

Edited by:
G. Kuppuram
K. Kumudamani

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We are highly indebted to Ashish Singhal Proprietor of M/s. Sundeep Prakashan for bringing out this monumental work in a very excellent form.

Introduction

The subjects of Science and Technology in India offers a rich field of study as it is known, the history of Indian civilization goes back to a remote Antiquity. But the scholars have made a comparatively thorough study of Indian literature and philosophy. It is a matter of gratification that the Indian scholars are taking interest also in the field of Indian science and mathematics, medicine and technology which originated quite early in the history of Indian civilization but uptill now not many publications as this subject have been brought out in India or elsewhere. It is well known that the Harappan people produced not only very important stone sculptures and terracottas but also bronze figures of great perfection of interest. In this regard one cannot resist the temptation of mentioning the importance of Mohenjodaro.

The Vedic people also know the use of various metals. Among the metals, gold is frequently mentioned in the Ṛigveda which was mostly obtained on the rivers of the north-west. Gold ornaments of various kinds such as earrings and armlets are also mentioned in the Vedas.

The Harappan people also made abundant use of gold as valuable. Gold have been found in several Harappan rites.

Irrigation has been playing an important role since the human civilization came into existence. Only the methods of irrigation have changed. In olden days

the types of irrigation did not have the variety. The methods of irrigation improved considerably from the beginning of the 20th century. The Kautilya's *Arthasastra* does not give the information about the way in which the irrigation is worked from the channel water but it gives the descriptions of dams, canals, the management of canal water including levying of levies.

This volume will be of great value to all the academicians as it has covered almost all the important topics related to science. The importance of agricultural Technology in medieval India, Development of life sciences, Science in agriculture during the British rule in India, have been described in detail by the authors of great standing. Life science in the 18th century, and its progress in the 19th century, establishment of tea gardens are the other important topics to be mentioned.

The ancient Indian Rishis with regulated perception have recognised the ecological significance of the natural instinct and adaptation of plants and animals which successfully withstand various environmental stresses and flourish in a welfare state and with sound rationale and reasoning. The fundamental laws of applied ecology have been perfected, the universal laws of external nature harmoniously blended with the sacred and supersensuous laws of the internal spiritual nature through symbolism and superimposition.

Arthasastra of Kautilya is probably the only book which deals with forgery in mints. Kautilya has prescribed heavy punishment for those who made fake coins or those who used them. Different type of metals were used to make the coins. Copper, silver and brass coins were more popular. Gold coins came into use

in the time of Kushana as there is no evidence of gold coins before the Kushana period. Although the number of gold coins issued by the early Indian kings is far less compared to silver and copper coins. Modern methods of mining gold ore were adopted towards the last quarter of the 9th century. The ancient people used lead in making coins.

The archaeological chemistry has assumed great priority and the analysing of archaeological specimens by a variety of physico chemical techniques, preferably non destructive is essential from several points of view.

One should get acquainted with the conditions and environments that the early man had to face. The fertility of land and alluvial deposits of the Indo gangetic plain are very significant points for the students. A wide range of information regarding the human cave dwellers in ancient India and how the change in river systems of north India took place has been vividly depicted.

For the students of history and science one can say that it is very important for them to know that there were no geological concepts during the ancient and medieval times in India.

The map making in China depended on route distances and directions. The classical Arab Cartography too depended upon route information as one can easily see it in the map published in Kramer's Edition of the Siratal-Arz of Ibn Hanqal of the 10th century. There has been a very little change in the theory of the Ptolemy regarding the process of determining the latitudes and longitudes.

Mathematics and Astronomy were also highly developed in Ancient India. The Indians excelled in

Algebra exceeding anything ever achieved by the Greeks. The earliest works of scientific Indian Astronomy are called Siddhantas, Aryabhatta who flourished in Patliputra in 476 A.D. reduced the early doctrines of mathematics and astronomy, reduced to a mere precise form. He maintained the rotation of the earth round its axis and explained the causes of eclipses of sun and the moon. Varahamihira was another great scholar who is known for his 'Brihatsamhita'. Another distinguished astronomer Brahma Gupta who flourished in 598 A.D. One of his very well-known work is *Brahma Saphuta Siddhanta.*

Indian Medical Science is said to have developed before the beginning of the christian era. According to the Chinese Buddhist sources. Charaka, was the official physician of King Kanishka in the first century A.D. His Ayurvedic works the *Charaka Samhita* is so well-known that he needs no introduction. Susruta was the next great authority as Indian Medicine.

The Baver manuscript of 5th century A.D. contains many statements agreeing with the passages found in the Charakas and Sustruta. The Astanga hiridey Ayurveda by Vagabhatta is also very well-known.

India witnessed the evolution of various types of architectural forms and structures, both the Hindus and Mohammedans are not only known for their grandeur but also for their intricate carvings and features.

The technological developments of India are also of no mean order. The art of metal casting, the glass making and gem cutting have also the admission of all lovers of art.

Various technological development including the use of iron has led to various social and military

development. The history of the Indian indigo, dyes and dyeing industry marks also an interesting study.

This volume contains some very precious articles describing the history of Indian technological and industrial development as well as that of mathematics, science, medicine, etc. Scholars in the field have depicted very authentic and useful information for the study of scientific, technological and Industrial development of India.

Preface

We have great pleasure in bringing out the volume, *History of Science and Technology in India* (in 12 Volumes) which contains valuable contribution on the various aspects of the history and developments of Indian Science and Technology. Precisely speaking the volume has a wide range of topics on the above subject. India is generally known for its religious and spiritual achievements but its achievements in the sphere of science and technology are equally important and interesting.

This volume can be divided conveniently into various sub-divisions including Health and Medicine, Mathematics, Astronomy, Geology etc. The knowledge of the Indian mathematics was carried out by the western world by the Arabs.

Indian technology in the classical age, assessment of science and Technology during the Harappan period; Indian science and its conceptual frame work; history of metallurgy during the different period; various aspects of glass technology in ancient and medieval India; some interesting architectural features of Indian monuments especially during the mughal period and many other related topics.

This volume, it is hoped will be of great importance and use to both general scholars and specialist in the field of Indian science, technology and industrial growth of the country, for it brings together as one place and array of sound and valuable discussion unfolding India's glory in scientific fields.

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1

The Technology of the Indus Civilization

D.P. AGRAWAL

The Indus civilization achieved an unprecedented uniformity and standardization over an area of more than half a million square miles. How they achieved it in the third millennium B.C. amazes everybody. Their products have neither the splendour of the Mesopotamians nor the over-ornamentation of the Chinese. A functional and utilitarian concept underlines all their works. But this simplicity and uniformity should not mask their revolutionary innovations and the sophisticated technologies they developed.

We discuss below the Harappan technology under the following categories : (1) Agriculture; (2) Transport; (3) Stone technology; (4) Ceramic Technology; (5) Metal technology; (6) Standardization; and (7) Innovations.

AGRICULTURE

In reconstructing the Harappan agricultural technology, modern practices give us a clue. Today wheat and barley are sown immediately after the monsoon floods

in the Indus plains (Sind) and reaped in March/April as *rabi* crops. This fertile alluvium does not need ploughing, irrigation or manuring today and one can extrapolate the same for the Harappans too. Sesamum and cotton must have been *kharif* crops, sown at the beginning of floods and reaped by autumn. No clear evidence of agricultural tools is available, though Kosambi identified a toothed harrow in one of the Harappan seals.

Another interesting evidence was obtained from the Pre-Harappan period at Kalibangan : a field, with furrows running at right angles to each other, in north-south and east-west directions was found. The distance between the two north-south running furrows was 1.9 m and between the east-west running furrows was 30 cms. It is interesting to note that even today mustard (in wider furrows) and horse gram (in narrow furrows) are simultaneously grown in that area. It is quite probable that this practice was adopted by the Harappans also in Rajasthan (Lal, 1971).

Table 1 gives the plant and fruit remains found at the Harappan sites. This shows that a wide variety of plants were cultivated (Kajale, 1974). Of the domesticated animals humpless (*Bos primigenius*) and humped bulls (probably descended from *Bos namadicus*) pig (*Sus cristasus*), buffalo (*Bos bubalis*) and elephant are represented at several sites. Camel remains are not so common. The horse-like terracotta from Lothal, *Equus* remains from Surkotda (Joshi, 1973) have been identified variously as horse or onager; the latter occurs wild even today in Gujarat. It is, however, obvious that the Harappans used cattle power for transport of goods and people.

TABLE-1

Plant remains from the Harappan sites

(After Kajale, 1974)

Plant Name	Latin equivalent	Site
1. Rice	Oryza sp.	(a) Kalibangan
		(b) Lothal
		(c) Rangpur
2. Barley	(i) Hordeum vulgare Var. nudum	(a) Mohenjodaro
		(b) Harappa
		(c) Kalibangan
	(ii) Hordeum vulgare *Var.* hexastichum	Mohenjodaro
3. Indian short wheat	(i) Triticum sphaerococcum	Harappa
(ii) Bread wheat	(ii) T. vulgare	Mohenjodaro
(iii) Club wheat	(iii) T. compactum	(a) Harappa
		(b) Mohenjodaro
4. Sesame	Sesamum	Harappa
5. —	Brassica juncea	Chanhudaro
6. Cotton	Gossypium arboreum	Mohenjodaro
7. Date palm	Phoenix sp.	Harappa
8. Water melon	Cucumis melo	Harappa
9. Pea	Pisum arvense	Harappa

TABLE-2

Percentage Composition

Site : Rangpur *(After Rao, 1963)*

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	O_2
1. 324 Celt PdIIc	—	—	—	—	Tr	—	91.2	2.6	2.1	4.1
2. 663 Celt PdIIa	—	—	Tr	—	Tr		91.35	4.09	Tr	4.6
3. 437 Bangle PdII	—	—	Tr	—	Tr	—	86.4	11.07	1.8	0.73
4. 417 Knife PdIIc	—	Tr	—	—	—	—	94.8	0.7	0.4	4.1
5. 330 Pin PdIII	—	1.88	—	—	—	—	91.8	0.6	5.86	—
6. 442 Pin PdIIB	—	1.86	—	—	—	—	96.6	Tr	0.8	0.74
7. 635 Ring PdIIa	—	1.4	—	—	—	—	96.66	Tr	0.38	1.56
8. 260 Ring PdIIa	—	0.45	—	—	—	—	96.1	Tr	0.2	3.25
9. 169 Bangle?	—	Tr	—	—	—	—	57.7	6.94	Tr	35.46
10. 170 Amulet PdIIa	—	0.57	—	—	—	—	77.6	Tr	0.1	21.73
11. 141 Pin PdIIc	—	0.24	—	—	—	—	65.4	6.78	0.51	27.08
12. 526 Knife PdIIa	—	Tr	—	—	—	—	59.0	5.28	Tr	35.72
13. 525 Knife?	—	1.08	—	—	—	—	59.6	2.69	—	36.63

TRANSPORT

In the development of a civilization, harnessing and efficient use of energy is essential. We have evidence that the Harappans used cattle power for transport and wind power for sailing their boats. The invention of wheel helped both transport and ceramic industry.

No carts have survived, but their tracks have been discovered in the Harappan sites and indicate roughly the same spans as used today. Terracotta models of carts are quite ubiquitous, though bronze models have been found only at Harappa and Chanhudaro. Both the lighter *ekka* type and the heavier bullock-cart type can be identified in these models and hardly seem to have changed through all these millennia. Rao (1973) has reconstructed three mains types of cart from Lothal: (i) concave or flat with a solid chassis; (ii) with a perforated chassis; and (iii) with a perforated chassis and a detachable cross-bar. On such a chassis wooden posts could be fixed to make a box-like structure to carry light merchandise, as it is done even today.

Boats were also used by the Harappans. One of the Mohenjodaro stone seals and a terracotta amulet depict boats. Rao discovered five clay models of boats from Lothal. Rao discerns "a sharp keel, pointed prow and high flat stern. It has three blind holes probably for stern, mast and ropes for the sail". Boats—with sails and without—were in use. The size of the boats is more difficult to judge. If the small stones 'anchors' (less than 50 cm diametre) found in the so called dockyard at Lothal are any indication, the boats must be very small indeed. As pointed out by

Pandya (1977), even a 50 tonnes barge requires an anchor of one quintal weight. The pots from Lothal have paintings of multi-ored, compared by Rao with the Late Gerzean examples from Egypt.

STONE TECHNOLOGY

We include under this heading the techniques used to make chert blades, beads and seals.

Taking out long blades of stone is an old technique which started from the Upper Palaeolithic times. A stone is selected and by alternate flaking across its shorter axis a crested guided ridge is made then a blow is struck along the longer axis of the core, at the end of this ridge. The impact results in a long blade which leaves two ridge on either sides and which again can be used in a similar manner to detach further blades. Plant (1973) pointed out that the most crucial factor in this technique was the manipulation of mass over the core surface which pre-determines the shape of flake to be detached. Blades upto a length of 20 cm have been recoreded. Rohri-Sukkur in Sind provided the source material for the baldes for the whole Harappan 'empire'. This, indicates a developed internal trade.

It is interesting to note that stone flaking techniques were used by the lapidaries also. Bead making is a living craft in Cambay even today and the craftsmen there produced beautiful long chert blades for our benefit with an effortless ease. Bead making required techniques of sawing, flaking, grinding and boring. The material used for beads was agate, carnelian, lapis lazuli, shell, terracotta.

TABLE-3

Percentage Composition

Key : Tr = Trace
+ = Present
(Analysed by the Sumerian Comm.).

Site : *Mohenjodaro Early levels*

Sample	details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni
D.K.	9474	—	1.08	—	—	Tr	—	98.02	—	Tr
"	9476	—	Tr	—	—	Tr	—	100	—	—
"	9477	—	1.4	—	—	Tr	—	98.6	Tr	Tr
"	9478	—	Tr	—	—	Tr	—	100	Tr	—
"	9483	—	—	—	—	—	—	100	—	—
"	9497	—	0.76	—	—	1.37	—	82.87	15.0	Tr
"	9503	—	—	—	—	—	—	100	—	—
"	9509	—	0.70	—	—	Tr	—	98.0	—	0.4
"	9514	—	1.4	—	—	3.0	—	86.3	12.3	Tr
"	9531	—	Tr	—	—	3.6	—	90.1	3.3	Tr
"	9548	—	Tr	—	—	Tr	—	88.5	11.5	Tr
"	9549	—	4.1	—	—	Tr	—	92.8	1.2	1.9
"	9555	—	2.2	—	—	Tr	—	97.2	—	0.6
"	9562	—	Tr	—	—	Tr	—	100	—	Tr

(Contd.)

TABLE-3 (Contd.)

Sample	details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni
"	9567	—	Tr	—	—	Tr	—	73.1	26.9	Tr
"	9583	—	Tr	—	—	—	—	100	Tr	Tr
"	9460	—	—	—	—	—	—	100	+	—
"	9472	—	—	—	—	—	—	100	+	—
"	9734	—	Tr	—	—	Tr	—	100	—	Tr
"	9740	—	Tr	—	—	Tr	—	87.77	12.0	0.23
"	9742	—	Tr	—	—	—	—	100	+	—
"	9744	—	Tr	—	—	—	—	100	+	—
"	9765	—	Tr	—	—	—	—	100	+	—
"	9767	—	Tr	—	—	—	—	100	+	—
"	9770	—	Tr	—	—	—	—	99.30	0.70	Tr
"	9784	—	Tr	—	—	—	—	100	—	—
"	9789	—	Tr	—	—	—	—	100	+	—
"	9808	—	Tr	—	—	—	—	99.18	Tr	0.82
"	9825	—	Tr	—	—	Tr	—	91.49	8.3	0.48
"	9828	—	Tr	—	—	—	—	100	+	—
"	9682	—	Tr	—	—	—	—	99.4	0.6	—
"	9714	—	Tr	—	—	—	—	100	+	—
"	9715	—	Tr	—	—	Tr	—	99.63	Tr	0.37

TABLE-3 (Contd.)

Sample	details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni
"	9722	—	Tr	—	—	0.86	—	76.19	22.2	0.75
"	9728	—	Tr	—	—	Tr	—	99.75	Tr	0.25
"	9366	—	1.1	—	—	6.3	—	87.7	4.9	Tr
"	9368	—	Tr	—	—	—	—	100	—	Tr
"	9376	—	Tr	—	—	Tr	—	100	—	Tr
"	9392	—	Tr	—	—	—	—	86.3	13.7	Tr
"	9421	—	Tr	—	—	Tr	—	100	—	Tr
"	9442	—	Tr	—	—	14.9	—	63	22.1	Tr
"	9446	—	Tr	—	—	Tr	—	99.04	—	0.96
"	9457	—	—	—	—	—	—	99.66	—	0.34

TABLE-4

Percentage Composition

Site : Mohenjodaro (After Marshall, 1931) (*Tr=Trace*)

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	S	O_2
Copper Lamp	—	0.03	0.15	0.88	0.02	—	96.67	—	1.27	0.98	—
Copper Lamp	—	0.49	—	0.98	Tr	—	97.07	—	0.31	1.15	—
Copper Lamp	—	—	—	—	0.09	—	96.42	—	0.35	0.36	2.78
Copper Lamp	—	1.51	1.30	Tr	Tr	—	92.49	0.37	1.06	Tr	1.01
Fragments of Implements	—	0.12	0.74	0.72	1.58	—	95.80	—	0.25	0.61	0.18
Celt	—	0.15	4.42	—	0.26	—	94.76	0.09	0.14	—	
Copper Chisel	—	0.59	3.42	0.10	3.28	—	92.41	—	0.15	0.05	—
Bronze Rod	—	0.15	1.96	1.15	0.17	—	91.90	4.51	—	0.16	—
Bronze Buttons	—	0.29	Tr	2.60	—	—	88.05	8.22	Tr	0.84	—
Bronze Chisel	—	0.35	—	0.35	0.70	—	86.22	12.38	—	—	—
Bronze Slab	—	0.42	1.17	0.33	0.11	—	82.71	13.21	0.56	—	1.49
Bronze Chisel	—	0.18	0.07	Tr	Tr	—	85.37	11.09	0.16	0.11	3.02
Bronze Lamp		—	—	Tr	0.17	—	83.92	12.13	0.17	—	3.61

gold, silver and copper. Fine steatite beads were made by pressing the paste through thin bronze tubes. The Harappans etched the beads by making patterns in alkali paste and then heating the bead till the alkali was absorbed. In the other type, the whole bead was made white with alkali heating and then a black design was painted, perhaps with copper nitrate solution.

Generally the seals were made of steatite. The stone was sowed and finished with the help of a knife and abrasive. The carying of animals and script was done with fine chisels and drills. To obtain a white lustrous surface the seal was coated with an alkali and heated.

CERAMIC TECHNOLOGY

The Harappan pottery is mostly wheel-thrown, red-slipped and painted with motifs in black. After the pot was made, it was dipped in a red-slip and painted and then fired.

Allchins (1968) have distinguished different techniques of pottery making. They suspect the use of footwheel which is still in use in Sind and Punjab, as flat bases with string cutting marks are quite common on the Harappan pots. Footwheel is put in a pit and is connected to a smaller turn table with an axle. The movement of the wheel is regulated by the foot. But in the post-Harappan times, for example at Rangpur, pots with rounded bellies come in vogue and probably indicate the use of spun-wheel. This wheel is an ordinary cart wheel and is spun with the hand. It can be given adequate momentum to run for more than a minute during which the pot should be given the shape.

TABLE-5

Percentage Composition

Site: Mohenjodaro from Lower Levels *(After Mackay, 1937-38)*

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	S
1. Pl. CXXVI, 5 DK 7535	—	0.33	0.66	0.25	0.59	—	91.01	6.14	0.48	0.12
2. Pl. CXXVII, 2 EK 7854 Axe	—	0.50	—	0.43	0.95	—	90.98	7.66	0.20	0.07
3. Pl. CXXVI, 2 DK 7856 Chisel	—	0.51	—	1.25	0.39	—	75.25	7.84	0.61	0.06
4. Portion of Axe DK 7861	—	0.10	—	0.14	0.22	—	88.49	9.88	0.60	0.06
5. Pl. CXXVIII, 1 DK 5486 Axe	—	0.34	2.10	Tr	0.20	—	80.56	1.76	0.58	—
6. PL. CXXXIII, 4 DK 6043 Chisel	—	0.02	1.58	0.54	Tr	—	86.92	8.56	0.68	0.07

(Contd.)

TABLE -5 (Contd.)

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	S
7. Pl. CXXVIII,15 DK 5360 Copper Frying Pan	—	0.33	0.80	0.18	0.05	—	81.94	0.37	0.21	0.14
8. Pl. CXXVII, 14 DK 7343 Bolt	—	0.29	0.24	—	0.81	—	97.23	—	0.89	0.10
9. Pl. CXXVI, 4 DK 7853 Axe	—	0.28	0.40	0.06	0.71	—	94.64	0.31	0.33	0.69
10. Pl. CXXXI, 32 DK 7859 Ingot (?)	—	0.56	0.24	—	0.82	—	95.23	—	0.41	0.48

This type of spun-wheel is now common in most parts of the subcontinent.

Only in the Saurashtra Harappan, a black and red pottery was also used. How exactly the bicolour was achieved is still a matter of debate but it is obvious that the supply of oxygen (air) was restricted to only those portions of the pot which were *oxidised* red; other portion, deprived of air, were *reduced* black. The pots were generally fired in round kilns with round tops, pierced floors with underlying fire-pits (Mackay,1938).

From some of the earliest levels of Mohenjodaro, a burnished grey ware with a dark purplish slip and a vitreous glaze has been reported (Marshall, 1931). It appears to have been a short-lived innovation, but probably is the earliest record of glazing in the world. In fact, glazed pottery became popular in India only during the Muslim period.

METAL TECHNOLOGY

A variety of gold ornaments were used by the Harappans. The main froms are beads, armlets, brooches, pendants and ornaments used on head-dresses and clothes. The Harappan gold is light in colour and has a high silver content which may indicate Kolar fields (Karnataka) as its source, as there also it srich in silver. It's possible that the Southern Neolithic cultures traded their gold with the Harappans.

It is noteworthy that the prolific use of silver is almost exclusively confined to the Harappans during the proto-historic period. Silver was not only used for ornaments

and embossing of conch shells, but also for making a variety of vessels.

Lead was used for plumb bobs and even for better fusibility in copper casting. Several ingots of lead also have been found. The Mohenjodaro galena ore examined by us showed traces of bismuth and antimony (Table 13). Zawar mines of Rajasthan have extensive deposits of lead and these could have been used by the Harappans.

Arsenic, tin and nickel have also been used to alloy copper but their sources are difficult to locate (Table 17).

The main metal used by the Harappans of course was copper. It has to be alloyed for better fusibility for complicated castings and also for obtaining more strength and hardness. We discuss below the Harappn technology of extraction, alloying and fabricating copper artifacts. We have also suggested some ore correlations (Agrawal *et al.* in press).

Copper is very meagre in the Pre-Harappan cultures. From Quetta and Isplenji mound-I (Pakistan) some simple copper artifacts along with the Quetta ware were recovered. At Damb Sadaat II and III only a few fragments of copper were reported. Only from Nal, a richer tool repertoire is known which comprises knives, bangles, axes, etc. From Kot Diji Pre-Harappan levels only one copper object has been reported and three pieces from the Pre-Harappan strata of Kalibangan. But the Harappans were very rich in copper artifacts.

We applied Friedman *et al's* (1966) technique to determine the probability of the use of different types of ores by the Harappans by analysing all the available data.

TABLE-6

Percentage Composition

Site : Mohenjodaro *(After Prakash & Rawat, 1965)*

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni
Bronze chisel	—	0.35	—	0.35	0.70	—	86.22	12.38	—
Copper lump	—	0.5	—	—	—	—	96.8	—	0.3
Bronze button	—	0.3		—	—	—	89.1	10.6	—
Bronze rod	—	0.41	—	—	22.83	—	69.76	6.65	0.33
Lump	—	0.41	—	—	—	—	99.93	0.26	—
Piece	—	1.24	Tr	0.77	—	—	97.79	0.07	0.13
Alloy piece	—	1.51	0.81	—	32.17	—	65.27	0.01	0.23
Piece	—	1.29	Tr	0.33	Tr	—	98.2	Tr	0.18
Fulcrum bar	—	—	2.23	—	0.10	—	96.16	0.88	—
Piece	—	0.09	—		—	—	99.63	—	0.28
Lump	—	—	4.38	—	0.90	—	93.56	0.79	0.41
Celt	—	0.36	0.48	—	1.03	—	95.45	2.47	0.21

(Contd.)

TABLE-6 (Contd.)

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni
Frying Pan	—	0.39	0.95	0.22	0.06	—	97.53	0.44	0.25
Crow bar	—	0.29	0.24	—	0.81	—	97.66	—	0.9
Celt	—	0.29.	0.40	0.06	0.73	—	97.15	0.32	0.34
Lump	—	0.58	0.25	—	0.84	—	97.43	—	0.41
Celt	—	0.33	0.67	0.25	0.59	—	91.40	6.16	0.48
Chisel	—	0.59	—	1.45	0.45	—	87.66	9.14	0.71
Lump	—	0.10	—	0.14	0.22	—	89.21	9.97	0.3
Celt	—	0.39	2.45	Tr	0.23	—	94.17	2.06	0.68
Bar	—	—	1.60	0.55	Tr	—	88.39	8.70	0.69

Our analyses show that both oxide ores and native metal were employed by the Harappans at Harappa and Mohenjodaro, though in some cases they appear to have used sulphide minerals (e.g., Chalcopyrite) also (Tables 13, 14, 17, 18, 26 and 28 in Agrawal, 1971). As native copper and oxide minerals generally occur on the surface outcrops of ore bodies, the preponderance of native and oxide forms may thus indicate use of fresh mines. At Rangpur (Table 2) no sulphide minerals seems to have been smelted. This may indicate the use of some fresh local mines. It may be pointed out here that large quantities of copper oxide ore were discovered from a brick lined pit from room 51, DK area at Mohenjodaro (Mackay, 37-38), a direct proof of the use of oxide ores by the Harappans.

We are also trying to use the method employed by the Russian workers (Chernykh, pers. comm.) in which they have identified the following groups of metals and their behaviour during smelting of the ores. Au, Ag, Sn, Bi, As, Sb are enriched more in the artifacts compared to the ores. Fe, Mn, Co, V and Ti go into the slag and Sn, Ge, Ga escape as gases during smelting.

Alloying is resorted to for imporving the ductility and hardness of metal. Pure copper is very soft. Tin has been employed (optimum range 8–12%) to improve the hardness and ductility of copper. We however find that there is a great variation in the concentration of tin in the Harappan artifacts. This may indicate either lack of control in alloying or use of a mixture of tin and copper ores. Out of the 177 analyses of the Harappan artifacts only 30% contained more than 1% tin, rest of the 70% were unalloyed. This may perhaps indicate poverty of tin; resources (Tables, 3 to 9).

Tin Content (%)	*In percent of artifacts*
1	70
1-7	10
8-12	14
12	6

At Surkotada (Gujarat) three artifacts have shown the presence of tin ranging from 2-8%. At Mohenjodaro, the upper levels of the site have 23% bronze tools whereas the lower levels have only 6% (Table 11). One finds that mainly knives, axes and chisels were alloyed because they need harder edges. Lothal artifacts also show a similar bias (Table 12).

Alloying was not confined to tin; but nickel, arsenic and lead (Table 17) were also used (Agrawal, 1971). Even 1% of arsenic increases the hardness of copper from 124 to 177 (Brinell hardness numbers.

The following percentages of artifacts were alloyed with As, Ni and Pb.

Alloying	*Artifact percentage*
As (1-7%)	8
Ni (1-9%)	4
Pb (1-32%)	6

A variety of techniques were used by the Harappans to fabricate artifacts out of copper metal. The Harappan tool repertoire tool repertoire comprises razors, knives, chisels, thin arrow-heads and spear-heads, axes and fish hooks.

The Harappans used a variety of pots and pans.

TABLE 7

Percentage Composition

Site: Harappa (*After Prakash & Rawat, 1965*)

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn
Celt	—	0.41	—	Tr	—Tr	—	91.52	7.85	0.22	—
Lance head	—	0.13	—	Tr		—	97.87	—	0.40	—
Rod	—	0.98	0.70	0.19	—	—	97.20	0.84	0.09	—
Dagger point	—	0.74	0.04	0.44	0.88	—	91.00	6.76	0.14	—
Dagger	—	0.40	6.69	—	2.85	—	89.88	—	0.18	—
Fragment	—	0.41	0.66	—	Tr	—	98.6	0.07	0.26	—
Celt	—	0.02	1.41	—	0.11	—	98.36	—	0.10	—
Chisel	—	0.09	0.36	0.31	Tr	—	92.61	6.43	0.20	—
Celt	—	0.41	Tr	—	0.20	—	91.32	7.85	0.22	—
Helmet sheetmetal	—	0.07	1.19	Tr	0.85	—	97.69	0.15	0.05	—
Chisel	—	0.34	1.10	—	0.52	—	87.42	10.45	0.17	—
Needle	—	1.37	0.40	0.42	0.10	—	88.79	8.75	0.17	—
Spearhead	—	1.11	0.06	—	0.70	—	97.66	0.33	0.14	—

(Contd.)

TABLE-7 (Contd.)

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn
Celt	—	1.11	0.06	—	0.70	—	88.37	—	0.14	—
Needle or awl	—	1.37	0.42	0.42	0.10	—	88.35	9.16	0.18	—
Saw	—	0.41	0.65	—	0.10	—	98.12	0.33	0.39	—
Chisel	—	0.39	0.60	—	0.20	—	94.12	3.60	0.29	—
Lance head	—	0.13	0.68	—	Tr	—	98.69	0.10	0.40	—
Needle	—	0.20	2.96	—	3.72	—	92.55	0.29	0.21	0.07
Dagger	—	0.47	0.26	—	0.98	—	91.87	6.42	Tr	

Superficial as well as metallographic examination of a number of Harappan artifacts was carried out by us. Some of earlier work was reported by Agrawal (1971). Our metallographic examination of the new samples from Surkotada, Chanhundaro and Mohenjodaro indicated knowledge of slow-cooling of the cast, annealing and cold work (Agrawal *et al.* in press).

The Harappan moulds were neither as ornate as the Chinese examples nor as intricate as the Mesopotamian ones. But they did possess the technology of closed casting as is evident from the mid-ribbed swords. Even 'lost-wax' (*cire-perdue*) process was known to them as shown by the dancing girl figurines from Mohenjodaro and animal toys from Lothal. It is strange that the Harappan technology shows extreme contrasts. On the one hand, they have masterpieces of lost wax casting and on the other a large number of axes from Chanhudaro and Mohenjodaro show a puckered surface.These are due to blow holes created by the absorbed gases while the metal is being heated in the furnace. This could have been 'poled' with green wooden boughs. The hydrocarbons in the wood reduce the oxide, but apparently it was not always done by the Harappans.

The metal fabricating techniques employed by the Harappans include 'sinking', 'raising', 'running on 'coldwork', 'annealing', 'rivetting', lapping' etc.

One of the most important and most difficult aspects of these sudies is the correlation of artifacts with the parent ores. In the beginning simplistic identifications were based just on the basis of the presence of As or Ni. Subsequent work has shown that a variety of techniques

TABLE - 8

*Percentage Composition**

Site : Mohenjodaro *(After Marshall, 1931)*

Sample detail		Sn	Ni	Sample detail		Sn	Ni
Late	period			Late	period		
D.K.	3479	—	—	D.K.	4059	—	0.15
"	4585	10.2	—	"	4087	—	0.26
"	4378	—	—	"	4068	10.7	Tr
"	3833	—	—	"	4041	—	Tr
"	4568	10.3	Tr	"	3648	—	Tr
"	4588	14.6	—	"	3612	—	Tr
"	3735	—	Tr	"	3630	11.6	Tr
"	4035	—	Tr	"	3611	—	0.14
"	4005	—	Tr	"	3712	—	0.24
"	3741	—	0.22	"	4599	—	0.04
"	3979	—	Tr	"	4600	5.6	0.21
"	3992	—	Tr	"	4396	—	0.05
"	3955	—	Tr	"	4400	—	0.07
"	3914	—	—	"	4361	19.1	Tr
"	3956	—	Tr	"	4451	—	—
"	3935	—	Tr	"	4303	—	Tr
"	3849	—	Tr	"	4431	—	—
"	3843	—	Tr	"	4565	—	Tr
"	3756	—	0.68	"	4585	—	Tr
"	3748	—	Tr	"	4330	—	Tr
"	4128	—	0.86	"	4384	—	—
"	3846	—	Tr	"	4260	—	—
"	4185	—	Tr	"	3566	—	0.81
"	4173	—	0.51	"	4642	—	—

*Balance was copper

TABLE-9

*Percentage Composition**

Site : Mohenjodaro (After Marshall, 1931) Key: + = *Present; Tr = Trace*

Sample details	Ag	Fe	As	Sb	Pb	Bi	Cu*	Sn	Ni	S
1. S.D. 1405	—	—	—	—	0.36	—	—	—	0.17	6.78
2. S.D. 1932	—	—	—	—	Tr	—	—	—	9.38	1.73
3. L. 3767	—	—	—	—	0.30	—	—	—	3.34	7.77
4. S.D. 2683 (A)	—	—	—	—	+	—	—	—	Tr	—
5. S.D. 2683 (B)	—	—	—	—	—	—	—	—	—	—
6. S.D. 2683 (C)	—	—	—	—	—	—	—	—	Tr	2.63
7. L .(?)	—	—	—	—	—	—	—	—	1.04	2.40
8. H.R. 1152	—	—	—	—	—	—	—	—	0.39	0.32
9. E. 602	—	—	—	—	—	—	—	14.4	Tr	—
10. H.R. 1472	—	—	—	—	—	—	—	—	1.49	0.23
11. V.S. 1572	—	—	—	—	—	—	—	19.0	0.23	0.43
12. V.S. 1416	—	—	—	—	—	—	—	—	0.09	0.28
13. D.K. 542	—	—	—	—	—	—	—	—	0.30	0.34
14. D.K. 1679	—	—	—	—	+	—	—	—	Tr	0.05
15. D.K. 2155	—	—	—	—	+	—	—	—	0.53	0.03

*Balance copper

TABLE-10

Percentage elemental composition of Harappan artifact samples obtained through atomic absorption spectrophotometer

Key : np = not present

Sample	Site	Description	Sn	Ni	Fe	As	Pb
P-2	Surakotda	Copper piece	8.08	0.0015	0.1603	0.153	16.090
P-5	"	Bangle piece	2.46	0.0009	0.0125	0.120	16.45
P-6	"	Copper ring	np	0.0092	0.192	1.491	1.3326
P-8	"	Copper bangle	4.30	0.0022	1.959	0.113	13.25
P-9	"	Copper point	np	0.0067	1.995	0.587	1.253
P-14	"	Copper piece	np	np	0.609	0.495	1.081
P-15	"	Copper piece	np	0.0189	1.044	1.000	np

TABLE-11

Type	Spear head	Knife	Axe	Sword	Chisel	Fish hook	Saw	Razor	Axe-adze	Arrow head	Sickle	Grand Total	Per cent
UPPER LEVELS:													
Total	9	31	13	2	36	5	2	12	1	7	—	118	
Copper	8	24	8	2	28	2	1	11	—	7	—	91	77
Bronze	1	7	5	—	8	3	1	1	1	—	—	27	23
LOWER LEVELS:													
Total	5	33	10	—	17	6	—	6	—	10	1	88	
Copper	5	33	7	—	15	6	—	6	—	10	1	83	94
Bronze	—	—	3	—	2	—	—	—	—	—	—	5	6

have to be employed to identify the minerals used by a particular culture. Pittioni (1957, 1959) correlated ores and artifacts by comparing their trace impurity patterns. We have here used a comparison of trace impurity patterns based on the common presence or absence of Ag, Fe, As, Sb, Bi, Pb, Sn, Ni, Zn, Mn, Co, Au, Al, Cr, Mo, Zr, W, Ti, Mg, V, Gd, P and Si. These elements were recommended by the Ancient Mining Committee (AMM, ·1959). It is interesting to note the close similarity in the trace impurity patterns of the Khetri copper minerals (Table 13,14), and the Harappan artifacts (Table 15). In the Khetri ore as well as in the artifacts from Chanhudaro/Mohenjodaro, Surkootada, Alamgirpur and Ropar gold is absent. Except for some artifacts (eg. P-109, P-121, P-128, P-130, P-177, (Table 15) which seem to be specially pure and may have therefore been derived from native metal, other artifacts show a fairly close resemblance through the common presence of most of the elements analysed by us.

TABLE-12

Alloying in Lothal Bronze Objects

(Rao, 1973)

Artifact	Tin%
Spear	2.27
Engraver	3.96
Mirror	5.47
Rod with grooves	9.02
Chisel	9.62
Bangle	11.82
Pin	13.80

TABLE-13

Spectroscopic analyses of Indian copper and lead ores analysed by us

Key : + = present
np = not present
nl = not looked for

Sample description	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn	Mn	Co	Au	Al	Cr	Mo	Zr	W	Ti	Mg	V	Gd	P	Si
P-56 Rakha chalcopyrite	+	+	np	+	+	np	+	+	+	+	+	+	np	+	+	+	np	np	np	+	np	nl	np	+
P-57 Rakha bornite	+	+	np	+	+	np	+	+	+	+	+	+	np	+	+	+	np	np	np	+	np	nl	np	+
P-58 Rakha chalcopyrite	+	+	+	np	+	np	+	+	+	+	+	+	np	+	+	+	np	np	+	+	np	nl	np	+
P-98 Ambamata chalcopyrite	+	+	np	np	+	np	+	np	+	np	+	+	np	+	+	+	np	np	np	+	np	nl	np	+

P-179 Mohenjodaro galena ore	np	np	np	+	+	np	np	np	np	np	np	np	nl	np	np	np	np	np	np	np	np	nl	nl	np
P-187 A Madras Pyrrhotite	np	+	np	np	np	np	+	np	+	+	np	+	nl	np	np	np	np	+	np	np	np	nl	nl	np
P-187 B Madras Pyrrhotite	np	+	np	np	np	np	+	np	+	+	np	+	nl	np	np	np	np	+	np	np	+	nl	nl	np
P-188 Singbhum Chalcopyrite	np	+	np	np	np	np	+	np	+	+	+	+	np	+	np	+	nl	nl	+	+	+	nl	nl	+
P-189 Khetri Chalcopyrite	+	+	+	+	+	+	+	+	+	+	+	+	nl	+	+	+	nl	nl	+	+	+	nl	nl	+

TABLE-14(A)

Percentage Composition

Indian Ores (After Agrawal, 1971) *Key : ns = not seen; nd = not detected*

Sample details	Ag	Fe	As	Sp	Pb	Bi	Cu	Sn	Ni
1. Chalcopyrite Singbhum TF-Cu-15	nd	>1.0	nd	nd	nd	nd	>1.0	nd	0.1 to 1
2. Pyrrhotite Ore-Madras TF-Cu-14	nd	>.1	nd	nd	nd	nd	<0.1	nd	.1
3. Chalcopyrite Khetri TF-Cu-24	<.001	>1.0	<.05	<.0025	<.0025	>.0025	>1.0	<.0025	0.2
4. Chalcopyrite Khetri	nd	26.93	4.28	—	3.81	0.23	4.82	nd	1.97
5. Copper ore Mohenjodaro	—	—	0.37	—	Tr	—	76.15	—	0.23
6. Lollingite Nal	—	49.3	43.6	—	—	—	0.7	—	—

TABLE-14 (B)

Percentage Composition

Indian Ores (After Agrawal, 1971) — *Key : ns = not seen; nd = not detected*

Sample details	Zn	Mn	Co	S	Al	Mg	Mo	Ti	V	Au	Cr	Gd
1. Chalcopyrite Singbhum TF-Cu-15	.001 to 0.1	.001 to 0.1	.001 to 0.1	—	0.1 to 1.0	0.1 to 1.0	.001 to 0.1	.001 to .1	.001 to .1	nd	ns	ns
2. Pyrrhotite Ore-Madras TF-Cu-14	<0.1	nd	>.1	<.1	nd	nd	nd	nd		ns	nd	ns
3. Chalcopyrite Khetri TF-Cu-24	<.0025	0.1	0.1	—	1.0	0.5	0.5	<.005	0.1	—	<.001	ns
4. Chalcopyrite Khetri	1.36	2.18	—	—	—	—	—	—	—	—	—	—
5. Copper Ore Mohenjodaro	—	—	—	1.12	—	—	—	—	—	—	—	—
6. Lollingite Nal	—	—	—	0.16	—	—	—	—	—	—	—	—

One can also date the ancient copper workings directly by the C^{14} method Table 16 gives all the available C^{14} dates for all the known mining areas. The earliest date (Agrawal et al.1976) so far however does not go beyond 1200 B.C. (Table 16) for Dariba mines of the Khetri belt. The search for older workings is on.

The total available data on the Harappan copper artifacts analyses, based on older works as well as ours (Agrawal *et al.*, in press), are given here: Tables 3 to 15).

STANDARDIZATION

The uniformity and standardization of the Harappan artifacts has baffled many an archaeologist. It assumes both an amazing administrative control over a territory of over half a million square miles and also over production and distribution. The shapes and designs of pottery, the types of copper tools, the weights and measures, the standard size of bricks (ratio 1:2:4), uniform layouts of the cities, etc., clearly indicate that they had realized the advantages of standardization.

A shell scale from Mohenjodaro and of ivory from Lothal indicate the Harappan measures of length. The Lothal scale has a length of 128 mm. The smallest divisions are 1.7 mm and the next unit is 33.46 mm (1.7 ´20). The Lothal scale is divided decimally. On the Mohenjodaro and Lothal scales a bigger unit of 67.056 mm can also be discerned. Both foot (13.2" or 33.5 cm) and cubit (20.5" ± .3" or 52 ± 0.5 cm) seem to be in vogue, as indicated by the measures of buildings and roads. For example, the main walls of the Harappan granaries measured 30 cubits and

their widths 10 cubits; some houses of Lothal measured 40 x 20 units of the Harappan foot (Rao, 1973). Rao (1973) has pointed out that the 17.7 mm Harappan division is very near the traditional angula measure of 17.86 mm of the Arthasastra.

Similarly the Harappan cubical weights show remarkable accuracy of standardization (Wheeler, 1968). In the lower denominations the system is binary : 1, 2, x $\frac{1}{3}$ x 8, 4, 8, 16, 32, etc., upto 12,800 which is comparable with the traditional Indian ratio of 1 : 16 (Rupee = 16 annas). The unit is equivalent to 13.625 gm. In the higher weights they have followed a decimal system, with fractional weights in one-thirds.

INNOVATIONS

The technological skills of the Harappans are not only reflected in their accurate and scientific system of weights and measures, but also in their new innovations. They made circular saws, true saws (with teeth and body set alternatingly from side to side for the maximum efficiency of cutting) and fine tubular drills. Probably the Harappans were the first to make these instruments.

For survey and measuring angles, they had a device which was identified for the first time by Rao at Lothal. It is made of shell. "It is a hollow cylinder with four slits on each of the two edges. When placed on a horizontal board it can be used almost as a compass in plane table survey for fixing the position of a distant object by viewing it through the slits in the margins. The lines so produced pass through the central point. If the opposite slits on one side are joined

TABLE-15

Spectroscopic analyses of the Harappan artifacts from India and Pakistan

Key : + = present ; np = not present

nl = not looked for

Sample description	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn	Mn	Co	Au	Al	Cr	Mo	Zr	W	Ti	Mg	V	Gd	P	Si
P-106																								
No. DK-10781 Mohenjodaro	+	+	+	+	np	nl	+	+	+	np	+	+	np	+	np	np	nl	np	np	+	np	np	np	+
P-109																								
No.49248/260 Mohenjodaro	np	+	np	np	np	np	+	+	np	np	np	np	np	np	np	np	nl	np	np	+	np	np	np	+
P-110																								
No. DK-9332 Mohenjodaro	+	+	+	+	np	np	+	+	np	np	+	np	np	+	+	np	nl	np	np	+	np	np	np	+
P-121 Mohenjodaro	np	np	np	np	+	np	+	np	np	np	np	np	np	np	np	np	nl	np	np	nl	np	np	np	np
P-128 Mohenjodaro	+	+	+	+	np	np	+	+	+	np	np	+	np	+	np	np	nl	+	np	+	np	np	np	+

(Contd.)

P-130 Mohenjodaro	+	+	np	+	np	np	+	+	+	np	np	+	np	np	np	np	nl	+	np	+	np	+	np	+						
P-180 Mohenjodaro spear head	+	+	+	+	+	+	+	+	+	+	+	+	np	+	+	+	nl	nl	+	+	+	nl	nl	nl						
P-181 Mohenjodaro bowl pieces	+	+	+	+	+	+	+	+	+	+	np	+	np	np	np	+	np	np	np	np	np	nl	np	nl						
P-177 Chanhudaro Celt	+	+	+	np	+	+	+	+	np	+	np	np	np	np	np	+	np	np	np	+	np	nl	np	nl						
P-182 Chanhudaro wire	+	+	+	+	+	+	+	+	+	+	+	+	np	np	np	+	np	np	np	+	np	np	np	nl						
P-45 Surkotda R No. 453	+	+	+	np	+	+	+	+	np	+	+	+	np	+	np	+	np	np	np	+	np	nl	np	nl						
P-70 Alamgirpur (Pd I)	+	+	+	+	+	+	+	+	+	nl	+	+	np	+	+	np	+	np	np	+	+	nl	np	+						

(Contd.)

Sample description	Ag	Fe	As	Sb	Pb	Bi	Cu	Sn	Ni	Zn	Mn	Co	Au	Al	Cr	Mo	Zr	W	Ti	Mg	V	Gd	P	Si
P-86 Ropar Celt No. 1172	+	+	+	+	+	+	+	+	+	nl	+	+	np	+	+	np	+	np	np	+	+	nl	np	+
P-87 No. 1397 Ropar Celt	np	+	+	+	+	+	+	+	+	nl	+	+	np	+	+	np	np	np	np	+	np	nl	np	+

by cords they cut at right angles, and if all the cords passing through the slits on both the margins are drawn on the same plane as shown .... they intersect one another at the centre and the angles so formed by the eight lines measure exactly 45° each. Obviously this instrument must have been used for inland survey and for fixing alignments of streets and houses" (Rao, 1973). This object is not unique at Lothal but was found at Mohenjodaro also and was mistakenly listed as an ornament. Recent explorations have produced this instrument from Pabhumath and other sites of Saurashtra (Atri, pers. comm.)

A unique find of a stone rotary mill from Lothal seems to attribute this revolutionary innovation to the Harappans. The only problem is that such an efficient use of manual energy should have found more common use elsewhere too. But so far this is the only such find reported from any Harappan site.

Sankalia (1974), however, attributes such rotary querns to historical times. He says that the rotary querns, of the heavy type with transverse holes for a two-way handle have turned up from numerous sites from 1st-2nd century AD/BC deposits. And this is exactly the type of rotary quern found at Lothal. Nowhere the lighter rotary quern with a hole on the top for a vertical handle (hopper type) has been found. He further emphasizes that nowhere in the several Chalolithic and Harappan sites dug so far, such rotary querns have been found (Sankalia, 1974).

The concept of town-planning was an innovation of the Harappans (and the Pre-Harappans). They laid out their town on a gridiron with streets running at right angles to each other. There was an extensive drainage

TABLE-16

C^4 dates on timber from ancient copper working

Sample No.	Site	Date in Yrs. B. P. $\frac{1}{2}$ = 5730 Yrs.	Locus	Samples from
TF-1117	Dariba Mines, Dist. Udaipur, Rajasthan	2310 ± 105	Depth 64 m, Layer 436	G.S.I., Udaipur.
PRL-208	"	2200 ± 100	East Lode old working Depth 4 to 5 m	Hindustan Zinc Ltd., Udaipur
PRL-209	"	3120 ± 160	East Lode old working Depth 263 m	"
PRL-210	"	1840 ± 130	Main Lode old working Depth 100 m	"
TF-1221	Kumbaria, Dist. Banaskantha, Gujarat	535 ± 90	Dumps behind Jain Temples, Kumbaria.	G.S.I., Ahmedabad
TF-1222	"	905 ± 85	"	"
PRL-53	Ambamata, Dist. Banaskantha, Gujarat	2110 ± 200	12 m distance in No. 3 west Drive of the underground mine	Mineral Exploration Corporation Ltd., Ambaji.

(Contd.)

PRL-66		850 ± 100	Bore hole No.100, N-W zone of Ambamata deposit	G.S.I., Ahmedabad.
TF-805	Bandlamattu Hill, Dist. Guntur, A.P.	900 ± 80	From contact of dolomite phyllite of Cumbum stage of Nallamallai series	Hindustan Copper Ltd., Ballapalle
TF-806		655 ± 90		
TF-373	Mailaram Distt. Khammam, A.P.	535 ± 90	One km west of Mailaram from a slag heap, 1 m depth	G.S.I., Hyderabad.
PRL-252	Ingalohul, Dist. Chitradurga	1730 ± 110	Shaft of the ancient copper mine	A.S.I., New Delhi

system which collected the sewage from each house. The drains were laid underground, below the streets. The lower city was always located in the eastern part and the citadel on the west. There is a remarkable uniformity in the layout of the cities—from Harappa to Kalibangan.

Another remarkable innovation was the technology of water proofing. The Great Bath is a marvel of water-proofing engineering skill. "To ensure that the bath was watertight, the floor was of bricks set on edge in gypsum mortar; the sides were similarly mortared, and behind the facing-bricks was an inch thick damp-proof course of bitumen held by a further wall of brick which was in turn retained by mud-bricks packed between it and on outer backed brick wall" (Wheeler, 1968).

TABLE-17

Arsenic %	No. of tools	Nickel %	No. of tools	Lead %	No of tools
0-0.3	19	0-0.2	22	Nil	15
0.3-0.5	5	0.2-0.5	18	0.5	14
0.5-1.0	10	0.5-1.0	6	0.5-1	12
1-2	7	1.0-1.5	2	1-3	4
2-7	7			3-5	2
	32		1		

CONCLUSION

We thus see that the Harappans had developed sophisticated technologies of casting and forging copper, of lapidary art, of ceramics and of agriculture. They invented new tools and instruments. They were perhaps

the first to realize the importance of standardization not only in systems of weights and measures but also in the products of mass consumption. They gave the world the concept of town planning.

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2

Some Aspects of Impact of Technology on Society in the Classical Age of India

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'The Classical Age' of India, as generally visualised by the Indian historians, refers to a span of over 400 years from the beginning of the fourth to the beginning of the 8th century A.D. In the prespective of Indian history, this Age seems to have witnessed a spring time efflorescence in creative endeavours, in literature, art and philosophy, in science and technology. The varied intellectual developments, the up-coming tide of craftsmanship, the innovative tendencies in arts and crafts which came upon the scene a couple of centuries preceding this period, appeared to have found new dimensions during the Classical Age.

Admittedly of special interest to us are the technical practices of the artisans and craftsmen and their social implications during this period. Yet the general output in the Classical age in different branches of science was also significant inasmuch as it reflected the intellectual mood towards astronomy, mathematics, medicine and the

problem of matter, motion, space and time. For the first time, a large number of specific scientific texts, in a succinct form, made their appearance with appropriate technical terminology in Sanskrit. The mode of precise and stylish presentation of scientific ideas was standardised. This resulted in an effective transmission of the knowledge orally from one generation to another. In such a presentation the religio-mythical elements were generally discarded in keeping with the new attitude. Not a few, indeed many, pursued the scientific activity which showed an openess of mind, a desire to sustain a searching attitude towards the observable world. Such an attitude was permissive of an assimilation of ideas even from elsewhere. Thus we notice that the Indian astronomy could absorb the Greco-Roman ideas and the Indian medicine, predominantly herbal as it was, showed inclinations towards recognizing the importance of mineral medicines. The assimilative character seems to have stretched itself, though a little later, to admit into its fold even the mercury-sulphur based alchemy from China and Arabia.

Techniques, though they had traditional constraints by and large, endeavoured to attain new heights both at macro and micro-levels. The now famous iron Pillar at Delhi and the copper statue of the Buddha (discovered at Sultanganj in Bihar) belong to this period. They testify to the skills of the metalsmiths of the time. The former has a height of about 7.5 meters with about half meter below ground (its diameter diminishing from about 40 cms below to 30 cms above). The pillar weighs more than six tons. Essentially of wraught iron, its composition is 99.72% iron; 0.8% carbon, 0.046% silicon, 0.006% sulphur and 0.114% phosphorus. It evoked a remark by a western economic

geologist (Ball, V. P., 338) that "It is not many years since the production of such a pillar would have been an impossibility in the largest foundries of the world, and even now there are comparatively few places where a similar mass of metal could be turned out." A fact of great significance is that the pillar has been existing for the last 1500 years or so without any rust or signs of decay. Of the technical skill which engendered this pillar there can be little doubt; but of its exact details we have but scanty information.

The huge copper statue of the Buddha is about 2.1 meters in height and nearly a tonne in weight. It is believed that it might have been cast in two layers, the outer layer possibly by the *cire perdue* process. The inner layer seems to have been cast in segments on a mould composed of sand, clay, charcoal and paddy husks using iron bands for holding the segments together.

According to the Chinese pilgrim, Hiuen Tsang, who visited India in the middle of seventh century A.D., a colossal copper image of the Buddha of about 24 meters height, and a brass temple of about 30 meters high were being built in an enchanting manner.

Apart from the impressive metal-workings, metal-smiths were active in producing agricultural implements, household articles and above all, the coveted jewellery. Gold, silver and precious stones founded new expressions and forms at the hands of metalsmiths. Attractive ceramics too made way into the social fabric, as also ivory and wood-carving Perfumery and toilet articles, fermented drinks and aphordisiac compositions, intricate garments of linen, cotton, bark-silk, muslin and hot silk as well as

other articles of personal decoration were sought after for an enriched living.

But the most important technology, then and now, was that of agriculture around which, more than any other, revolved the socio-religious life of the times. Naturally agriculture and the associated land systems received a far greater attention. A noticeable impact of this was a sort of a partial feudalization of the land system and the growth of local units of production. The hold of the state on the lands began to loosen its authoritative trends. The resultant decentralization had the desired effect on improved methods of agriculture.

Although the key note of the Indian society continued to be governed by the caste system, even the Brahmins began to take interest in agriculture as land owners, of course, with certain royal restrictions. Others too realized the potential wealth of the land for an enriched living. A necessary concomittance of this was that, at least in certain parts of India, the area of cultivation was extended and rural settlements increased despite the fact that it was prone to fragmentation of land under various ownership. The priests also had the legitimate opportunity to indulge in agricultural practices, although their superior status enabled them to have peasants of lower caste to do the actual agricultural operations. Such was generally the case in respect of land holdings granted to temples and other places of worship.

In view of the importance of agriculture for the material well being of all classes necessity arose of making plausible forecasts and determining the quantities of rainfall. This resulted in the evolution of certain types of

almanac computations, and observations on the seasonal changes. Rain-gauges were thought of, and a sort of calender for sowing, mid-treatment of crops, harvesting etc. was developed. The priestly class in general provided the desired knowledge with the result with the actual tillers had to depend upon their advice for agricultural operations. The time was ripe for the codification of agricultural technology. Many extant texts of this period contain quite a large number of references to the agricultural practices such as, the treatment of seeds, the preparation of the soil, manuring, rotation of crops, irrigation, protection of crops from diseases and pests, tillage implements etc.

The technology of agricultural implements received a new fillip, the village carpenters and blacksmiths assuming an important role in the society. They were, however, inter-woven into the land economy with certain shares in the agricultural produce. The black-smiths, of necessity, produced ploughshares, sickles, spades, iron rods and bond pins of improved quality. Obviously they exercised great care towards selection of the ore, carbon and heat treatment. A text of the period even refers to a ploughshare of about 2 kilograms in weight and ten centimeters in breadth. Such heavy ploughshares enabled either deep ploughing or bring into cultivation the virgin soil. With its extensive application in agricultural operations, iron seems to have emerged as the most important metal of the common man. The sharp iron implements were effectively used to clear the jungles with a view to acquiring arable land and establishing new settlements. Even a Buddhist monk, according to a Mahayanist text, was permitted the use of earthen or iron pots, while he was forbidden to use those of other metals including copper.

Iron technology in particular and metal-working in general had an indelible impact on various aspects of the social life, for they provided not only new avenues of employment but also useful articles of life. Of special social significance was the jewellery craft to which there are copious references in the literature pointing to the fact that it enjoyed the patronage of the kings as well as the general public. No less than 22 precious stones including diamond, sapphire, emerald, ruby, beryl, amethyst, topaz, coral, agate, conch-shell etc., were dexeterously used. The characteristics of gems were well-known the pearl-workmanship was of high quality especially.

The jewellery craft had its own special techniques. A careful examination of precious metals and stones, determination of their defects, discarding of the counterfeits and, above all, the tiny but accurate weights had to be evolved. The technique of testing gems was even elevated to the status of one of 64 fine arts of the time. The social value associated with the jewellery provided a new stimulus to the growth of this technology and a new status to the craftsmen associated with it.

Theology, during the period, held sway over the masses. Iconography became a specialized art with appropriate iconometry. In keeping with their ability for the society, the metal-workers, cotton and silk weavers, carpenters also enjoyed the deserved patronage. In some parts of the country, the craftsmen were able to become part of the guilds and thus participate in commercial enterprises.

The technical art of perfumery and cosmetics had perhaps a sustained impact on all sections of the society.

The rather widespread demand for perfumes by all sections of people resulted in the rise of a class of artisans among whom, in turn, there were specialists in different kinds of perfumes—such as the blended ones, mouth perfumes, scented water for bathing, incense, powders etc.

In the history of human progress, one would observe that the techniques — their innovations and their usefulness to the society at large—were noted for their innate capacity for bringing about certain changes in the social structure and even in the value-systems. A pertinent question is: 'Did the varied techniques which promoted the material progress in the Classical Age of India result in the release of such factors or forces as could effectively alter the social structure or usher in new values of life?' It would seem that, even during the so-called Golden Prime of India, the age-old division of the society into four casts continued to circumscribe the society. There were no doubt, during the Classical Age, welcome departures in the matter of certain social customs and duties associated with each of the castes.

While admittedly there might have been some flexibility or mobility with regard to certain occupations like trade and agriculture in which the higher castes also were involved whenever it suited them, an intra-flexibility seems to have been absent among those engaged in metal-working carpentery, weaving, construction of buildings etc. Each chose to continue with the traditional technique of his family without attempting to learn other techniques.

Even among the different productive artisans and craftsmen, there was many a caste distinction marked by certain social regulations. Among them too were vertical

divisions without any horizontal communication or social mobility. Generally they were regarded as being of low castes, and economically subservient to the higher castes, both in the urban and rural areas. Their work remained more as handicrafts and their existence depended largely on the whims and fancies of the higher castes. What the Frenchman Bernier saw in India centuries later was perhaps equally true in the Classical Age. To quote Bernier (p. 255): "It should not be inferred from the goodness of manufacturers that the workman is held in high esteem, or arrive at a state of independence. Nothing but sheer necessity or blows from a cudgel keeps him employed; he never can become rich, and he feels it not a trifling matter if he has the means of satisfying the carvings of hunger and of covering his body with the coarsest raiment. If money be gained, it does not in any measure go into his pocket, but perplexed how to guard against some acts of outrage and extortion on the part of his superiors." In addition, there were certain social injunctions pointing to the inferiority of some productive occupations like leather-working. Such a situation acted as a hindrance towards innovative interactions among the various caste-governed social strata.

Be that as it may, even the privileged castes who enjoyed in no small measure the fruits of techniques appeared to move along the already chartered social grooves. The social status of women, like that of the low castes, was indeed inferior. They were denied the right to be educated even in religious matters. With the denial of education to the women and to the low castes who were in a great majority, it would perhaps be not wrong to

conclude that nearly three-fourths of the population bordered on illiterate slavery of some sort or the other.

Not that the Classical Age of India did not have centres of learning. There were famous Universities in Nalanda and Valabhi which attracted students from far and wide. The curriculum of studies included, besides the religious texts, logic, astronomy, mathematics, and medicine on the one hand and the techniques of arts and crafts on the other Nevertheless, the former was generally meant for the priestly and the warrior castes, while the latter was for the agricultural and mercantile communities. The study of arts and crafts was of practical nature. It was concerned with the knowledge of precious metals and stones, textiles, perfumes, sowing seeds and quality of soils, weights and measures. But the lowest castes to which belonged the artisans and craftsmen were not able to have access to this knowledge. Such a preferential educational system was hardly condusive to engender a change in the social value-system. Albeit the continued social rigidity through which several techniques had to plough their weary way, the economic organisation was developed to suit the internal and the foreign trade. There were laws of wages, mutual relations of labour and capital, guilds and partnerships. Of special significance are the codified texts which dealt with laws concerning a large number of products. The appreciably efficient economic organisation and a wide variety of merchandise resulted in the development of inland and sea-routes to a considerable extent during this period. There was a flourishing inter-oceanic trade betwen the east-coast of India and China, Indonesia and Ceylon as well as between the West-coast and Persia, Arabic and Ethiopia. There were land trade

routes too by way of Central Asia and Bactria This intercourse, had the potentiality of absorbing new techniques from outside in a couple of centuries later. As it happended, paper technology came to India in the eleventh century, and a little later possibly pyrotechniques, enamelling, intricate glass-working etc.

In perspective, the techniques and the craftsmen seemed to have been coeval with a rather regressive environment of social and religious rigidity in the Classical Age of India. The situation did not appear to show signs of improvement even in the sucuring centuries, despite the dexterity of craftsmen of which we have ample evidence.

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Some Aspects of Paint Technology in Ancient India

S.K. BHOWMIK

INTRODUCTION

The history of Indian painting is very old. Even certain surviving mural Paintings date from the pre-christian era. Their present existance after the neglect and depredations of several centuries indicates to the soundness of the methods and processes evolved and devised by the artists of ancient India. This fact naturally leads us to an enquiry into the paint technology evolved and followed by the ancient Indian artists.

It is obviously difficult for general public to understand the paint technology of ancient India. Unless one sees an master artist at work, it is not possible to comprehend ancient paint technology. The scientific analysis of artist materials is the only alternative to understand the technical processes involved in the creation of ancient works of art. A stylistic examination of ancient paintings remains superficial without the scientific examination. However, the data with regard to technique of early Indian paintings are available from the ancient literature bearing on the Arts

commonly known as *Śilpa* texts. The literary data on *Śilpa* text may provide us the basic information for useful investigation into the painting techniques of early periods of Indian history and culture.

According to several *Śilpa* Texts and a number of *Āgama* works, *citra* means sculpture in the round, *citrārdha* means relief sculpture in the round and *citrābhāsa* means painting. Paintings on walls, paper, cloth and wood of early periods of Indian history constitute one of the most valuable heritage of India. These paintings are a unique expression of Indian creative genius. The production of a successful painting calls for a considerable degree of technical skill and a well developed technique not only in the execution of th. works of art but also in the manufacture of various kinds of paints.

PIONEERS IN THE STUDY OF SILPA TEXTS

Ram Raz[1] was the pioneer in the study of *Śilpa* texts in modern times and his work entitled "Essay on the Architecture of the Hindus" is a monumental work which came to the light in 1830. Another memorable work worth mentioning is the text of viṣṇudharmottara published by the Venkateswara Press, Bombay, in the year 1913. In 1918, T.A. Gopinath Rao[2] published a research paper, on Indian painting and in his research paper, he discussed the technical aspects of Indian mural paintings on the basis of *Śilparatna* and the *Aṁśumadbhedāgama* which are two sanskrit texts belonging to south India. Thereafter in 1924, Stella Kramrisch translated into English the *citrasūtra* section of the *Viṣṇudharmottara*. By this translation work,

a valuable sources-text on painting was brought to the notice of scholars and art-lovers. Further contribution was made by Ananda K. Coomaraswamy who published in 1934 a revised version of chapter 41 of the *Viṣṇudharmottara*. In this revised version, he threw freshlight on the subject by clarifying many technical terms on painting which had been confusing and baffling the scholars for a long time. After this work, further study on the Viṣṇudharmottara was carried out by Priyabala Shah who published the text of third *Khaṇda* of the *Viṣṇudharmottara* in 1958 and its translation in 1961.

Another achievement of Coomaraswamy is his publication in 1928 of the english translation of the *citralakṣaṇa* section (chapter 46) of the *Śilparatna*. His most significant contribution in the study of *śilpa* texts on painting is his publication on "the technique and theory of Indian Painting" in 1934 based on the study of the section on painting in the *Abhilaṣitārtha-cintāmaṇi* which he translated from Sanskrit into English along with his interpretation of technical details. It is thus clear that Dr. Coomaraswamy was the first scholar who made critical study of Artist's materials and Artist's technique based on *śilpa* texts. Prof. Percy Brown gave information about the technique of Paintings of Mughal period. Dr. Motichandra also discussed techniques used in Mughal Paintings in his monograph on the subject. K.P. Jayaswal may also be considered as one of the pioneers in the study of Indian canonical texts on paintings. He published in 1923 the result of his study on painting under the publication entitled "A Hindu text on painting" based on his critical study of the chapter 46 of the *Śilparatna*.

P.N. Bose should be credited for his monumental publication entitled "Principles of India *śilpaśāstra*'. He also scholarly discussed the "*citralakṣana*", an ancient text on icono-plastic art by Nagnajit, based on B. Laufer's edition. V. Raghavan has brought to the light a number of unknown treatises on painting such, for example, as the Kāśyapaśilpa, the Sāraswathīya-citrakarmaśāstra, the Nārada śilpaśāstra etc.

C. Sivaramamurti discussed the social and material background of the painters in ancient India and published a paper entitled "The Artists in Ancient India" Dr. Motichandra rendered a valuable service by publishing his monumental work entitled "Technique of Mughal Painting."

WELLKNOWN SILPA TEXTS DESCRIBING TECHNICAL ASPECTS OF PAINTING

The well known *śilpa* texts of ancient India have discussed certain technical aspects of paintings of ancient India. Of them (1) *Viṣṇudharmottara*, (2) *Samarāṅgana-Sūtradhāra*, (3) *Aparājitapṛccha*, (4) *Abhilaṣitārtha-cintāmaṇi* (or *Mānasollāsa*), (5) *Śilparatna*, (6) *Nāradaśilpaśāstra*, (7) *Kaśyapaśilpa* deserve special mention.

Among non-canonical literature, mention may be made of (1) *Nāṭyaśāstra* of Bharata, (2) *Agni-purāna* (3) *Arya-mañjuśī-mulakalpa*, a Buddhhist text, (4) *Pañcadasī* (5) *Atthasālini*, a Buddhist Pali text. These texts are of special importance from our point of view.

PIGMENTS AND COLOURS

Śilpa texts attach special importance to the topic of

colours and pigments. They supply ample information on the process of obtaining pigments for colours used in Indian Painting.

Indian Artists of ancient times knew the characters of primay and secondary colours from a very early date. The chapter 27 of the *viṣṇudharmottara*, the earliest of the *śilpa* texts states that the primary colours are white (*śveta*), red (*rakta*), yellow (*Pīta*), black (*kṛṣna*) and green (*harita*). Both the *Mānasottāsa* and the *Aparājitapṛcchā* ratain four of the five primary colours of the *viṣṇudharmottara* and rejected the green (*harita*) of the Ist list and blue (*nila*) of the second list of the *viṣṇudharmottara*. According to the *śilparatna*, the five primary colours are white (*śveta*), yellow (*pīta*), red (*rakta*), black (*kajjala*) and a dark shade called *śyāma*. In connection with the decoration of a *Maṇḍala*, the Agni-purāna mentions a list of five primary colours, viz. white (*śukla*), red (*raktā*), yellow (*haridrā*), black (*kṛṣna*), and *śyāma* and this list agrees with that of the *śilparatna*.

1. White

According to *śilpa* texts, the list of primary colours begins with white. It is very important to Indian Painter. White pigment acts as the medium for almost all colours. It is used as priming the ground on wall, panel or canvas. The work of painting proper begins with the application of white coating on a prepared background.

White colour has been referred by all the *śilpa* texts, dealing with painting as one of the primary or pure colour. According to the *Mānasollasa* (Mān. II, I, 139) after plastering the wall, it should be primed with the white prepared either from conch-shell, oyster-shell etc., or from white clay which is either kaolin or gypsum. The mineral

containing white pigments should be thoroughly ground with the help of a stone-pestle.

According to *śilparatna* (ŚR, I, 46, 28-34), white pigment can be obtained by two methods: (1) From conch-shell, Oyster-shell etc. or white-clay which carefully ground and then mixed with the exudation of wood-apple (i.e. *Kapittha*) or *nim*; (2) The powder of lime should be mixed with the Juice of *Keravāla* fruit (probably cocoanut) and be ground again. The lime white is then prepared by levigating it with warm water and by repeatedly stirring it up. Among the Indian Painters, white colour prepared from conch-shell or oyster shell was more popular than those prepared from the white-clay or kaolin.

2. Red

The red colour and the various shades of red have been mentioned in the canonical texts. According to Mānasollasa (Mān. II, I, 156), crimson (*śona*) colour is produced from red lead (*darada*), the blood-red colour (*rakta*) is produced from the juice of lac (*alaktarasa*), the red (*lohita*) colour is produced from red ochre, *Śilparatna* (ŚR I, 46, 117-118) mentions that red lead (*sindūra*) should be used for soft red, red ochre for middle red and the juice of lac resin for deep red. According to *Kāśyapaśilpa*, Jātiphala or the Jasminium Grandiflora is also a source of vegetable red pigment.

Red Ochre (gairika or geru)

Red ochre is a popular pigment and it has been used extensively by Indian artists in both murals and miniatures. According to *śilparatna* (ŚR, I, 46, 119), it was prepared by pulverizing the red clay (*gairika*) on stone for about one day

and then colour can be obtained by washing it in pure water.

Red Lead (Darada or Sindura)

This colour is prepared by roasting white lead in open air till it turns into a deep red hue. According to *Śilparatna* (ŚR, I, 46, 120), red lead (*Sindūra*) should be ground for twelve hours alongwith water and, after a gap of five days, it should be ground again for a full day. Thereafter it should be mixed with *nim* gum as the binding medium.

Vermilion or Crude Cinnabar (Hiṅgula)

The *Mānasollāsa* and the *śilparatna* do, not mention clearly about *hiṅgula* (crude cinnabar), the *viṣṇudharmottara* (VD, III, 40, 26) however clearly mentions hingula as source of red. The *Jaina-citrakalpadruma* (I, pp. 45 and 119) clearly mentions the method of preparation of this colours. The crude cinnabar is ground in a mortar and it is reduced to fine smooth paste by grounding it with the help of sugared water or lime-juice which is better than the sugared water. After allowing cinnabar to settle, the yellowish powder is carefully drained off. The process is repeated 15 times or even more to obtain purest cinnabar. It is again reduced to fine paste by grounding it with lime-juice and gum. The reafter it is dried in the form of tablets.

Realgar or Red Arsenic (Manaśśilā)

It is a sulphide of arsenic and it appears in the colour of orange-yellow. According to *Śilparatna* (I, 46, 120), realgar is levigated to fine powder and then mixed with *nim* gum and then used as a colour.

Red Lac (Lākṣārasa)

The lac-resin as the source of red colour is mentioned in the *viṣṇudharmottara* (VD, III, 40, 26). It is a dark red resionous substance known as lac or lacca produced on certain trees by certain types of insects. Muni Punyavijayaji described the method of preparing lac-dye in his book entitled *Jaina-citrakalpadruma* (I, p. 40, fr. 55). According to him, pure water is required to be boiled at a high temperature. Powder of lac-resin is then gradually mixed in the boiling water. While mixing, the water should be stirred all the time to prevent the solidification of the resin. After this, the temperature of the water should be raised, and at the interval of 10 minutes, the powder of the lode and borax should be thrown in. To ascertain whether the colour was ready, a pin is to be dipped in the prepared solution and then a few lines are to be drawn on the hand made paper. If the ink does not split, then the colour is ready and the solution is removed from the fire. After the water dried, the residue is used as colour.

Madder (Mañjiṣṭha)

The use of madder as deep red dye for cotton textile is well known in ancient India. Europeans also knew its use from ancient time. It is known in Europe as "Turkey red" which indicates its eastern source. It is a pigment of organic origin *śilpa* texts make no reference to madder as a colouring substance. Probably *mañjiṣṭha* was found unsuitable for painting. It was however a popular dye for colouring textile. Madder colour is prepared from the madder root of 2 to 3 years old creepers of madder plant known as *mañjiṣṭha* (Rubia Tinctorium).

Carmine (Kṛmiraga or Kermes)

Śilpa texts are silent about this pigment. Carmine is, however, used in making western Indian miniatures. This colour was not popular in India. It is of organic origin, and is the product of a species of insect known as *Krimidānā* which breed on *cocti*. It may be noted that only the female insects yield the colour.

3. Yellow (Haritāla or Orpiment)

The orpiment yellow was a popular pigment in the medieval western India. It was used in Western Indian palm leaf manuscripts.

Orpiment is a sulphide of arsenic. It is found in nature as stone. It has a vivid yellow colour, but more often it slightly inclined towards orange. It occurs in mountains, river-beds and other places. The mineral orpiment is generally collected from mountain or river beds. It is then washed in pure water. It is reduced to fine powder by grounding on a stone. The powder is then transferred in a jar containing water and agitated the water in the jar for a few moments and then left to settle. The orpiment will float on the water leaving the impurities below the water. The floated particles of yellow is then collected in a suitable container. The process is to be repeated as long as necessary for isolating and removing all impurities from it. The purified yellow orpiment thus obtained is properly dried in the sun. Before using in painting, it is mixed with gum in required proportion. The *Mānasollāsa* (Mān. II, I, 157) and the śilparatna (ŚR,46,41-45) have made elaborate reference of this yellow orpiment.

4. Black

The silpa texts mention the importance of lampblack as a black pigment. The *Mānasollāsa* (Mān,II, I,157) mentions kajjala or lampblack for black pigment. The Śilparatna (ŚR, I,46,47-51) refers to Kajjala as one of the pure black colours and also describes the method of its preparation.

5. Blue

The blue pigment is made from two sources of blue, organic blue and the inorganic blue. *Viṣṇudharmottara* (VD, III, 40, 25-26, 81, 23 and 16) mentions *Nīla* (indigo) and *rājavarta* (Lapis Lazuli) as two substances from which blue pigments are obtained. Indigo blue (nila) is extracted from a plant which is Botanically known *Indigofera*. It is at Present primarily used as a dye, but once it was also popular as pigment. Indio was known to the ancient Egyptians and it was imported to Europe by the Greeks and the Romans from India. It was not used in the wall-paintings of Ajanta and Ellora. It was used rarely in the illustrated palm leaf manuscripts of Bengal, Nepal and Western India.

The ultramarine blue was prepared from Lapis Lazuli (rajavarta) and used in Indian Paintings from a very early date, Mānasollāsa mentions this pigment. Probably the lapis lazuli stones or the ultramarine pigments were imported to India from Persia as the *Śilpa* texts do not mention any method on the manufacture of Lapis Lazuli.

6. Metallic Colours

It was the very old practice in India to use metallic colours in paintings. The earliest of our *śilpa* texts, the

viṣṇudharmottara (VD, III, 40, 25-26) mentions the names of metals like gold (*kanaka*), Silver (*rajata*), Copper (*tāmra*) and bronze (pitala) as the substances from which pigments should be made. The later silpa texts, the *Mānasollāsa* and the *śilparatna* state methods only for the preparation of gold pigments. The metallic colours were known in ancient India but their use was limited as the methods of their preparation were not only complicated but also costly. The *śilparatna* describes two methods of application of gold powder and gold leaf in painting. The method of liquifying gold by chemical treatment was known during the time of *viṣṇudharmottara* but this chemical method was not mentioned in the *Mānasollāsa* and the *śilparatna*. The absence of metallic colours including the use of gold colour in the paintings of Ajanta, Bagh, Badami and Ellora was conspicuous.

Mixed Colours

The *śilpa* texts prescribed methods on the preparation of various mixed coloures (*miśra-varṇah*). The *viṣṇudharmottara* (VD, III, 40, 18) mentions that hundreds of colour may be prepared by mixing primay colours (*mūlaraṅga*) as per one's own idea and intelligence. The *viṣṇudharmottara* describes the basic principles governing the laws of making secondary colours and shades of those secondary colours. The *mānasolliāsa* (Mān. II, I, 161-164) enlisted a number of secondary colours prepared by mixing two types of primary colours. The *śilparatna* (SR, I, 46, 134-142) mentions a list of secondary colours usually practised by the contemporary painters. The *Kāśyapaśilpa* gives a longer list of mixed colours in comparison with the *Mānasollāsa* and the *śilparatna*. In all these *śilpa* texts, one

would find that the Indian painters had observed certain principles while making mixed colours. It must be noted that these studies were rarely founded on authentic data. The descriptions, on artist's materials and artist's technique included in these works are often vague and misleading. The correct interpretation of the information based on the *śilpa* text, where the pictorical technique is treated at certain length is not always possible on account of mutilations and corruptions which occur too often in their texts.

PIONEERS IN SCIENTIFIC INVESTIGATIONS INTO THE TECHNIQUE OF INDIAN PAINTING

Several technical investigations were carried out by Paramasivan[3] and Haldar[4] on the technique of ancient Indian Paintings which throw valuable light on pigments and binding media used in the paintings of Ajanta, Bagh, Ellora and some temples of south India. Paramasivan has identified the following pigments at Ajanta: yellow ochre, carbon, lime and calcium sulphate, terreverte and lapis lazuli from cave II, and terreverte and yellow ochre from cave XVI. A.K. Haldar identified the following pigments from the murals of Bagh caves in Madhya Pradesh: earthen mineral and stone pigments indentical with those eimpolyed at Ajanta were used. The application of lac-red was known at Bagh.

The pigments identified by Paramasivan at Ellora are yellow ochre, red ochre, terreverte, carbon, lime and gypsum.

The pigments employed by the early medieval painters of Travancore and Cochin were identified as yellow

ochre, red ochre, terreverte, carbon and lime from the Travancore paintings[5].

It is thus found that yellow ochre, red ochre, carbon and lime are the commonly accepted pigments of the Indian painter and all these pigments were identified in the cave-paintings at Ajanta, Bagh and Ellora. These pigments also identified in the temples of various districts of further south.

TECHNICAL STUDIES

The technical studies involving the technique of photomicrography, micro-chemical study (chemical microscopy technique) and thin-layer-chromatography have been explored for providing better identification of artists materials specially pigments and their binding media.

A systematic application of chemical analysis, micro-chemical as well as small particle analysis is essential for understanding composition of paint layers, binding media and pigment.

Several such technical studies on paintings were undertaken by the writer of this article at the Baroda Museum. Polarized light microscopy, micro-chemical texts, thin layer chromatography, X-ray diffraction analysis and other analytical methods have been employed to reach firm chemical identification of pigments.

Such technical studies are able to shed more lights on several art historical problems including detecting date of production, lines of artistic influence and inter-connection between medieval centres of painting production.

SCIENTIFIC INVESTIGATION

(a) Types of Paintings Investigated

The paintings investigated belong to medieaval and post-medieval periods; and may be classified into four groups.

1. Mural Paintings.
2. Manuscript miniatures on paper.
3. Miniature paintings on wooden covers of plam-leaf manuscripts.
4. Miniature paintings on paperboard.
5. Scroll paintings on cotton cloth.

(b) Examples of a few important Paintings included in the Study

Some of the most important paintings included in the technical studies carried out by the writer of this article may be mentioned below:

1. Paintings of the Ajanta caves.
2. A number of manuscript miniature paintings illustrated in the *Kalpasutra* manuscripts in the possession of the L.D. Institute of Indology, Ahmedabad and the Baroda Museum, Baroda.
3. Early miniature Paintings executed on wood cover of palm-leaf manuscripts from South India, now in the Possession of the Oriental Institute of the M.S. University of Baroda.

A number of minature Paintings of the Mughal and Rajput school in the possession of the Baroda Museum, Baroda.

5. Two ancient painted scroll of *vijnaptipatras* of 17th cent. A.D. of Jahangir time. Size : (1) 6 ft. × 1 ft.; (2) $3\frac{1}{2}$ ft. × 1 ft. These two paintings are now in the possession of the L.D. Institute of Indology, Ahmedabad.

6. A 40 feet long scroll painting on cotton cloth depicting the auspicious events in the life of the Adinatha, the first of the twenty-four Jain Tirthankara in sixteen scences. It has been dated to 17th cent. A.D.; and is 40 ft. long and $3\frac{1}{2}$ ft. wide. This painting is now in the possession of the Bombay Museum.

FINDINGS OF TECHNICAL STUDIES

This study has revealed interesting data regarding pigments and their binding media. It has been found that there are mainly three varieties of pigments used in Ancient India— (1) Mineral pigments, (2) Vegetable pigments, and (3) Artificially manufactured pigments.

Under the category of mineral pigments, most frequently occuring pigments are : vermillion, Red lead, Orpiment, yellow-ochre, gold in the form of powder, natural ultramarine (Lapis), Azurite blue, malachite green, calcium suplphate, White lead, silver in the form of powder, and zinc white. Zinc white pigment is generally found in paintings of later periods i.e. in paintings dated to 18th and 19th centuries.

Under the category of vegetable pigments, the most prominent pigments are: Madder red and Indigo-blue (natural). The presence of indigo - blue has been detected in paintings of late periods.

Under the category of artificially manufactured pigments, the most frequently occuring pigments are : Lampblack, Verdigris green, ivory black.

As regards binding media, it may be said that animal glue as binding medium was used for gold pigments; while for the remaining pigments stated above, vegetable gum was used as binding medium.

As regards 'priming' or ground coating substance, it may be pointed out that animal glue was detected in many cases as the ground coating material particularly in paintings on cotton cloth and paper. Lead white as ground coating material was detected in a number of early paintings on paper. But zinc white as ground coating material was detected in paintings of Late periods.

CONCLUSION

Artistic excellence and durability are the two fundamental qualities which determine the masterpieces of works of art. The perfection in using artist materials and techniques by a master artist brings about artistic excellence and durability of a masterpiece.

A scientific study of the technical aspects of early Indian paintings is essential to understand the paintings materials and paint technology which are important aspects of Art history. The knowledge of Art history is

incomplete without the knowledge of painting materials and paint technology. Such a study may be helpful in the reconsturction of the history of paint technology of ancient India.

The forgeries in art are very common in these days. Technical studies are useful in the detection of forgeries in art of the present day. It is also valuable in the enquiry into the scientific care and restoration of works of art.

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4

Rock Art Technology

YASHODHAR MATHPAL

There are many publications which exclusively or partially deal with prehistoric and protohistoric Indian techniques of making stone tools (Sankalia 1964, 1970), potteries (Mackay 1938, Sinha 1968, Misra 1968 and Lal 1968), terracottas (Sankalia 1970:26-28), beads (*Ibid*: 35-44) and metals like copper and bronze (Hegde 1965, Agrawal 1968). So far no light has been thrown on the methodology of art which is found on various rock surfaces. Despite the facts that India is one of the six major regions of rock art in the world, the first country do discover Stone Age paintinges and also the first country to realize the prehistoricity of these paintings it is indeed, a matter of both surprise and sorrow that the study of Indian rock art has remained in its elementary stage. More than 150 sites with several thousand painted caves and incised boulders have so far come to light. Of these two-thirds are situated in Central India. A 60 km long belt with 45 sites of painted shelters has been found in the source region of the Betwa. It is perhaps the biggest concentration of rock paintings so far known on our globe. Similarly, Maski region in

Karnataka is one of the two richest repositories of incised drawings of the Old World. The other region is Sahara in north Africa. The oldest specimens of rock art in our country date back to the Mesolithic stage (c. 10,000-5,000 years before present or B.P.) and the youngest to the Early Historic period some 1,500 years B.P.

On technological ground, Indian rock art can be divided into two major groups: the pictographs or painted drawings and the petroglyphs or abraded drawings. The pictographs are confined mainly to the sandstone formations of the 'Vindhya Sastem', and the petroglyphs to the granite hills in Peninsular India. The sandstone being a sedimentary rock, weathers very easily and in such a way that caves and hollows of differet sizes and shapes are created due to the decay of softer sediments. Man has used these caves or rock shelters during Stone Ages, and decorated the walls and ceilings with scenes of hunting and other day-to-day activities. In South India, the Neolithic groups living on the granite hills which are heaps of loose boulders have incised drawings of cattle on the rough surfaces of these boulders. Thus, rock art is found on the walls and ceilings of naturally formed caves and on loose boulders without any preparation of ground such as chiselling, grinding, somoothing and plastering of rock surface. Since the techniques of making pictographs totally differ from those of the petroglyphs we will describe the technical aspects of both the forms, separately.

PICTOGRAPHS OR ROCK PAINTINGS

The rock paintings constitute a major portion of rock art. Besides sandstone the paintings are found on slate and

lime stone surfaces. The entire technique of making paintings can be studies into the following sub-headings

(a) Background; (b) Painting techniques; (c) Drawing material; (d) Binding aids and (e) Painting process.

(a) Background

As already indicated that all the figures on rock are sound on a bare surface without any ground preparation. Smoothness of rock was not always a considering factor in the choice of a spot for paintings are found on the ceilings and inner walls of the shelters. Shelters situated at commanding heights and exposed to rising and setting sun rays are noticed having a profusion of paintings. Large shelters suitable for habitation purposed are deficient in art while small hollows and niches bear beautiful drawings. In painted shelters too some particular portions were selected for painting and repainting. Later artists painted over the already existing ones without erasing them. Thus as many as 16 superimposed layers of paintings creating sometimes a jumble of figures, are noticed in some shelters. Vertical rock faces and small chambers at hardly accessible heights also contain elegant drawings. No where any background colour has been applied. Natural formations on rock such as crevices, hole and depressions are also used to enhance the effect and to minimize the labour.

(b) Painting Techniques

In Indian rock paintings four techniques are noticed for creating figures. These are: Wet transparent colour (Water colour) technique, Wet opaque colour (Tempera or oil colour) technique, Crayon (Dry pastel colour) technique and Stencil (Spray colour) technique. In the older phases

most of the figures are executed with the transparent colour technique. Earth colours were rubbed and diluted into water to prepare thin and transparent pigments. These pigments were then used for drawing large shadwographs (silhouettes) of animals, and to fill huge portions on rock with single colours. Pigments prepared from iron-oxide of different shades, are used for the transparent technique. Colours like emerald green and white are applied in opaque technique. Stick-shaped micrographic figures of humans and small-sized outlines of animals in the earliest phase are drawn with this opaque technique. In the paintings of Early historic period, dark red and crimson are also noticed as opaque colours. The third category of painted figures is of the crayon drawings. There are very few drawings executed with this dry colour technique. Figures are directly drawn like rough sketches with the nodules of dry red colours. The stencil technique was applied for making negative hand prints. To create such a negative impression the hand was placed on a plain rock surface. The diluted colour was sprayed out with mouth through a narrow pipe probably a piece of hollowed bone. This technique was very common in Upper Palaeolithic Europe and in Aboriginal Australia till recent past in latter case. A very attractive negative hand print is found in shelters IIG-8 on the Bhonrawali hill near Bhopal.

Two other ways of making hand prints were used by the Stone Age artists. One of them is to out line the desired hand after putting it on rock wall, and the other is to stamp a colour-dipped hand on wall and thus create a positive hand impression or a shadowgraph of the hand. Outlined drawing of a boy's hand is seen in shelter IIIF-24 at

Bhimbetka in Central India. As many as 222 positive hand prints in five different colours (white, light red, drak red, crimson and burnt umber) are found in different shelters at the same site. Of these 165 hand prints are of right hands while 57 belong to the left hands. Besides, first prints, finger prints and finger tip dots are also created by stamping them on the rock.

(c) Drawing Material

(i) Colours:

Rock painters have always used mineral colours found in the local geological formations. Of all the colours it the haematite red (iron-oxide or *Geru*) which has been lavishly used by prehistoric man and primitive man, as well. It is still the main colour for folk artists. The use of *Geru* is as old as the man himself is. Prof. L.S.B. Leakey (1958:1100) has noticed its use at the Chellean Stage I at Olduvai George in Africa. During Acheulian period (c. 400,000 - 100,000 B.P.) it was used in Europe (White 1973:63) and India (Paddaya 1976). The ochre mine of Wilgie Mia in Western Australia has been extensively quarried by aborigines from time unknown (Mulvaney 1975:260). In India, nearly all the prehistoric sites dating between 10,000, and 5,000 years have yielded nodules of iron—oxide. Archibald Carlleyle was the first scholar to collect the partially used nodules of *Geru* from the excavation of the painted shelters near Sohagighat in Mirzapur district as back as 1867 (Smith 1906:187). H.D. Sankalia (1974:252), G.R. Sharma (1964:78) and V.N. Misra (1973:4) have found haematite from the Mesolithic sites of Gujrat, Uttar Pradesh and Rajasthan, respectively. From the excavations

of the painted shelter IIIF-23 at Bhimbetka, in which the present author also participated, 32 colour pieces with tell-tale grinding marks on them have been collected from the Mesolithic layers. These pieces belong to nine different colours (e.g. orange, light red, scarlet, crimson, burent umber, raw umber, raw sienna, sepia and grey) (Mathpal 1984:188). Wakankar (1975:18) has recorded the finding of a heap of iron-oxide, a stone palette and a painted stone from his excavation in the Modi shelter in the Chambal valley. At Bhimbetka he has found yellow ochre, terra verte and maganese in shelter IIIA-28.

The second colour is white which is found in several yellowish and bluish tones. The present writer has found a slender white lime stone stick (9.5 x 2.5 x 2 centimetres) with well marked ground facets in shelter IIIE—14 at the same site. White colour used in the Palaeolithic cave paintings of Europe, is identified as pipe clay or slaked lime (Breuil and Lantier 1965:176). A.J.H. Goodwin (1953:22) assumes that the white colour applied by the South African painters was prepared from China-clay or bird droppings or the latex of euphorbias. It seems that the Indian rock painters had used lime stone for white pigment. The stick found by the author was tested on rock and it gave a bright colour. Twenty-one colours have been noticed in the paintings of 133 caves at Bhimbetka. These include white, bhuish-white, pale-white, bright-yellow, yellow-ochre, raw-sienna, raw-umber orange, dark orange, vermilion, scarlet, light red, dark red, burnt sienna, burnt umber, crimson, dark crimson, purple, sepia, emerald green and black (for details see Mathpal 1984:187-189). Nowhere else in the prehistoric world so many colours were used as in India.

(ii) Colour palette:

Except for the stone palette found by Wakankar at Modi, no object has been found which can be assigned as a colour palette or a colour container. Since there are large shadowgraphs of animals exceeding to one metre in a few cases and painted with thin transparent colour, it is likely to assume that the artists used to prepare a good quantity of pigment before starting painting and this diluted pigment was kept in some container be it a rind of gourd, a shell of wood-apple, a bamboo mug, an wooden vessel, a leaf-cup or a leather bowl. The necessity of such containers is felt more while painting at great heights, below the roof and at hardly accessible places.

(iii) Brushes:

Similarly, we have no archaeological record of the implements used in paintings. In ancient Sanskrit literature four different words have been used for an artist's brush. These are *Kurchika* (*Kuchi* in Hindi), *Tulika*, *Lekhani* and *Vartika* (*Vatti*). *Kurchika* is a brush made of *Kurch* a stiff grass and *Tulika* of *Tul* (cotton). The *Lekhani* is a blunt pointed stick and *Vartika* is a rolled piece of cloth or cotton. *Tulika* and *Vartika* are still used by the folk painters. The Saora artist of Orissa uses a twig slightly splayed at one end (Elwin 1951:188). The Australian aboriginal painter draws figures with a strip of chewed bark or with soft feathers (Mountford 1961:7). The Ice Age European painters, according to Breuil and Bergerkirchner (1961:26), were probably using their fingers, frayed twigs and feathers as brushes. Cockburn (1883:59), one of the earliest students of Indian rock art, presumed that the paint was applied with a fibrous brush while the linework

was done with a pointed stick. Writing on the technical aspects of the Raigarh rock paintings, Percy Brown (1923:251) says that the colour was probably applied by means of bamboo or reed brushes, the implement most likely being a stiff blunt point rather than a brush, and the treatment of some of the painted surfaces seems to prove this. Wakankar and Brooks (1976:5) think that the paintings were executed with a brush made of palmetto twig. However, the present writer believes that the rock painters have used brushes those were fine pointed as well as capable of holding a substantial load of pigment. The micrographic outline drawings of animals and humans in the earlier phases cannot be drawn without a fine tipped brush which is pointed as well as soft to run on the rough surface of rock. Similarly, large shadowgraphs painted in transparent wet colour technique can only be created with a brush which can pick up a sizable quantity of diluted colour at the time of handling.

Painting on ceiling and vertical wall that too unprepared and coarse, is an arduous job. What to speak of primitive ones, even the latest fine sable hair brushes create a problem in such conditions. The moment one starts painting, the flow of colour diverts towards painter with the half-slanted position of the brush. There was no lack of smooth fur of wild animals for the hunter-gatherer people. The best hair for making a fine brush were available with the squirrels. Cotton from *Semal* (*Bombax malabaricum*) could have been used for making a *tulika*.

(d) Binding Aids

After knowing about the antiquity of rock paintings, the first question asked by a common man is, "How these

colours have survived so long?". Then there are other related queries (e.g. Have the painters mixed some kind of fixative or binder with colours? What was that fixative? Was it an animal fat? Were the painters knowing that their pictures would survive so long? etc.) To answer all these questions the author takes a very common example of our bathroom. We all known that an iron bucket leaves a circular mark on the floor where it was kept for a long time. It is a stain mark which is everlasting and cannot be disfigured by water. Similarly, the colours used by the rock painters were mostly prepared from the iron-oxide. These colours applied on rock surface start to react chemically with the rock minerals and oxidization with in the rock, causing colours to penetrate thus making pictures visible even after the colours are eroded.

But there are a few other colours also which are not derived from iron-oxide. Paintings executed with these colours have also survived. It seems, therefore, likely that some kind of adhesive was mixed to make the colours durable. The *Brihatsamhita*, *Vishnudharmottarapuranam*, *Shilparatna* and *Manasollasa* refer to several kinds of fixatives to be used for ground coating and binding materials. Names as *Vajralepa*, *Vajrasamghat*, *Ashtabandha*, these *sthambanas* were prepared from various decoctions of fruits and bark of trees (Bhatacharaya 1963:427-28). A kind of *Vajralepa* prepared by boiling a piece of fresh buffalo skin in water is described in the Abhilashitarthchintamani (Sastry 1926:195). The Chitrasutram (40/29) describes several herbal decoctions made from the plants of *Tulsi*, *Bhunimba*, *Champa*, *Kusha* and *Maulshiri* (Jha 1959:456). It further says that paintings covered with feathers of peacock, or with a cloth dipped

in *Durva* juice, survives for many years and cannot be damaged by water (*Ibid*). The possibility of animal fat in colours used by rock painters all over the world, has been widely accepted by the scholars (Mathpal 1984:189). Blood, vegetable juices (Breuil and Begerkirchner 1961:26), melted honey (Bandi 1961:76) and hyrax urine (Goodwin 1953:23) are other items considered as probable binders (or vehicles) for colours. It is true that the herbal decoctions and *Vejralepas* described in our Sanskrit literature are far younger techniques in comparison to the prehistoric rock paintings, nevertheless, man's knowledge of local flora and fauna is found much deeper in primitive societies than that of ours.

(e) Painting Process

On rocks, sometimes, the paintings are found at considerable heights. In Shri Lanka, Erwin (1983:44) has found some paintings on a vertical granite wall at 30 m above the ground. At Bhimbetka, Bhonrawali, Lakhajuar and Raisen in Central India and at Badami in Peninsular India, the present writer has noticed many small painted chambers which can be approached only through trees, artificial platforms or scaffolds. The awe-inspiring image of a mythical boar in shelter IIIC-19 at Bhimbetka is on the ceiling of a mush-room-shaped huge rock at a height of nearly 10 m from the surrounding ground. it can be supposed that artists made use of trees close to the shelters and also constructed some temporary platforms to stand on where such trees were not available. In many shelters at Bhimbetka and Bhonrawali, the tamarind trees are still found grown up inside the shelters and developed parallel to the rocks. Such trees present natural platforms by their

nearly horizontal trunks to work on ceilinge and at heights. The artists have simply to lie supine and paint. During his field work at Bhimbetka, the author used to reach to the shelters situated at the top of vertical cliffs, with the help of trees grown up in rock fissures. A fallen down dry tree trunk with alternate forks was also a good substitute for a scaffold.

PETROGLYPHS OR ABRADED DRAWINGS

Mainly confiend to South India, the petroglyphs are found in three forms: engreavings, carvings and bruisings. The engravings are the outline drawings of humans, animals and any other objects incised on rock surface with the help of a sharp cutting tool or any other way, carvings are the bas-relief figures modelled out from the background by lowering down the surrounding surface of the figures and bruisings are the drawings created by rubbing down the upper surface of rock.

Although the art of engraving on bone, antler and soft stone is widely recorded from the Upper Palaeolithic Europe, yet engraving on hard and rough stones like granite, is restricted to the post-Mesolithic stages only. There is an exceptionally old specimens of an engraved ox-rib found at a depth of some 40 m in a cave deposit in the valley of the Dordogne in France, which dates back to some 250,000 years before present (Marshack 1975:85). Engraved bones, ostrich egg-shells and bone chisels are also recorded from the Palaeolithic levels in our country (Sankalia 1978). During Mesolithic stage man had used chert and chalcedony borers and burins besides knives, sickles, arrow heads and spearheads. At Mhoenjodaro,

Chanhudaro, Lothal and Kalibangam metal and stone drills and chisels were used to make steatite seals, ring stones, stone vessels, semi-precious stone beads and shell bangles. But for producing an engraving on a granite boulder one does not require a sharp metal tool. The engraver has simply to smooth down the crystalline particles of rock surface with a hard stone to create an outline of the drawing. Besides Maski, Piklihal, Tekkalkota, Sangankallu and Bellary, the engravings are found in Laddakh, Gilgit and Attock areas in the extreme north and north-west part of the sub-continent A few engravings are noticed by the author on the Nagori hill near Sanchi and at Devidhura in Pithoragah district of Uttar Pradesh. All these engravings were probably done with some sharp metal tools.

The only record of rock carvings is that mentioned by F. Fawcett (1901: 409-421) from the Edakkal cave in Kozhikode district of Kerala. These so-called carvings are located in a total darkness. Erwin Neumayer (1983:44) has described them as the engravings with deep scars. Recently a press reporter (*The Pioneer* 1986; 14 January : 7) has also described them as engravings in broad grooves. Since the present author has not visited the cave, it is difficult to know their exact nature.

The bruisings are found only on the granite boulders. As already mentioned that Maski is the biggest repository of such drawings. The technique of making bruisings is similar to that of engravings on such rocks. After drawing a rough outline of the figure, the standing out crystalline particles of rock covered by the drawing are to be rubbed down till the desired figure emerges in white colour from

the dull pale background. This rubbing of rock surface can be done with any hard stone or a metal object. Finally, there are pits and cup marks carved out on vertical monoliths and horizontal rock surfaces belonging to the Megalithic cultures. These shallow holes were probably made by gently blowing with a stone or iron hammer, the way conical mortars on boulders are still made in the villages of Kumaon.

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5

Textile Tools as Depicted in Ajanta and Mughal Paintings

ISHRAT ALAM

India's textile industry formed the core sector of Indian non-agricultural economy before the 19th century, textiles were at the top of the India's list of exports. In the present paper, an attempt is made to study the technological aspects of textile production in medieval India. The material on the subject comes from the most miscellaneous sources, to be found in diverse places where the description is often unintentional or incidental, in Persian texts, European travellers' accounts and pictorial evidence, all to be checked with modern information about 'traditional' methods. In addition to these, standard works on history of technology of west, Iran and China have been consulted,[1] for purposes of comparison with other cultures and for descriptions and interpretations of techniques.

It was known in antiquity that fibres, particularly cotton, needed cleaning before they could be spun into yarn. The harvested cotton was left in the sun for a few days to weaken the adherence of seeds to the floss in order to facilitate the former's separation from the floss. In India, this has been done traditionally by two methods, *viz.*, the

Plate 1. Cotton-ginning with the roller and board (on the left side) and the Cotton-gin (on the right side). Note the ginning methods, G. Yazdani, *Ajanta, The Colour and Monochrome Reproductions of the Ajanta Frecoes based on Photography*, PL XII, A Palace Scene : Dancing Girls (Mahajanaka Jataka?)

Plate 2. Cotton ginning : the roller-and-board, *Miftah-ul-Fuzala*, British Library Or. 3299, f. 100a.

Plate 3. Cotton ginning : the cotton-gin, G. Yazdani, *Ajanta, The Colour and Monochrome Reproductions of the Ajanta Frescoes based on photography*, Pl. XII, Palace Scene : Dancing Girls (Mahajanaka Jataka ?)

Plate 4. The bow-sting device, the mallet, *Miftah-ul-Fuzala*, British Library Or. 3299, F. 126 b.

roller-and-board and the cotton-gin (*charkhi*). Both the frames appear to be of ancient origin. The roller-and-board was present in nearly all ancient civilizations for various purposes. The roller used to be cylindrical. It was worked with hands on a flat board. This technique has possibly been depicted in one of the Ajanta frescoes (*Plate* 1).[2] The Ajanta depiction remains unsupported textually in India until the fifteenth century when the *Miftah-ul Fuzala*, an illustrated Persian dictionary, described and figured a wooden instrument called *chubakin* or *chublin*,[3] used for separating cotton from the seeds (*Plate* 2).[4] This method was also practised in medieval China.[5] This was probably a wooden roller, but whether it was moved by hand or feet is not made clear. The foot-manipulated roller was widely used in the 19th century in south India.[6] Perhaps, both practices may be used in different regions.

The use of cotton-gin was an improvement in cotton-ginning technology. Its use in ancient India is established by its depiction in the Ajanta fresco. The representation that Schlingloff recognised to be of a bow-string device to separate cotton fibres is really a charkhi (*Plate* 3). It is depicted with its characteristic rectangular frame, which has nothing in common with the bow-string device.[7] Both the upper rollers are visible, though they are slender. Quite reasonably, a crank-hanlde is not shown (since the crank is a very late comer in technology). The woman is feeding cotton between two rollers and probably moving the rollers with the other hand. This makes it almost certain that the device was known to Indians by the mid-6th century A.D.[8]

The Indian origin of this device has no other

Plate 5. The same instruments as in Plate 32, *Miftah-ul-Fuzala*, British Library Or. 3299, F. 126 b.

Plate 6. Spinning-wheel, *Miftah-ul-Fuzala*, British Library Or. 3299, f. 151a

Plate 7. Yawning and stretching, *Miftah-ul-Fuzala*, British Library Or. 3299, f. 268b.

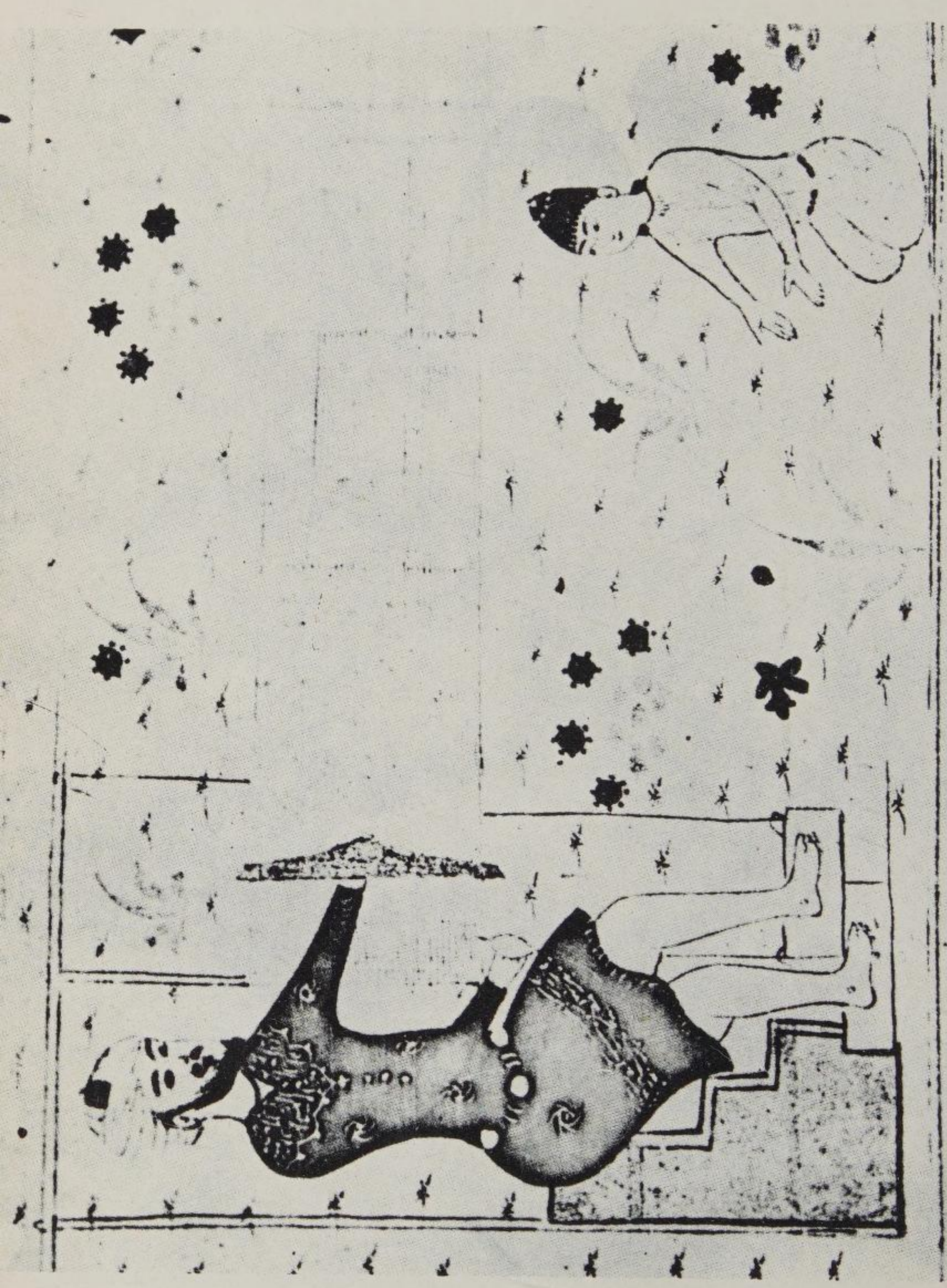

Plate 8. Loom with treadles, *Mitfah-ul-Fuzala*, British Library Or. 3299, f. 262a.

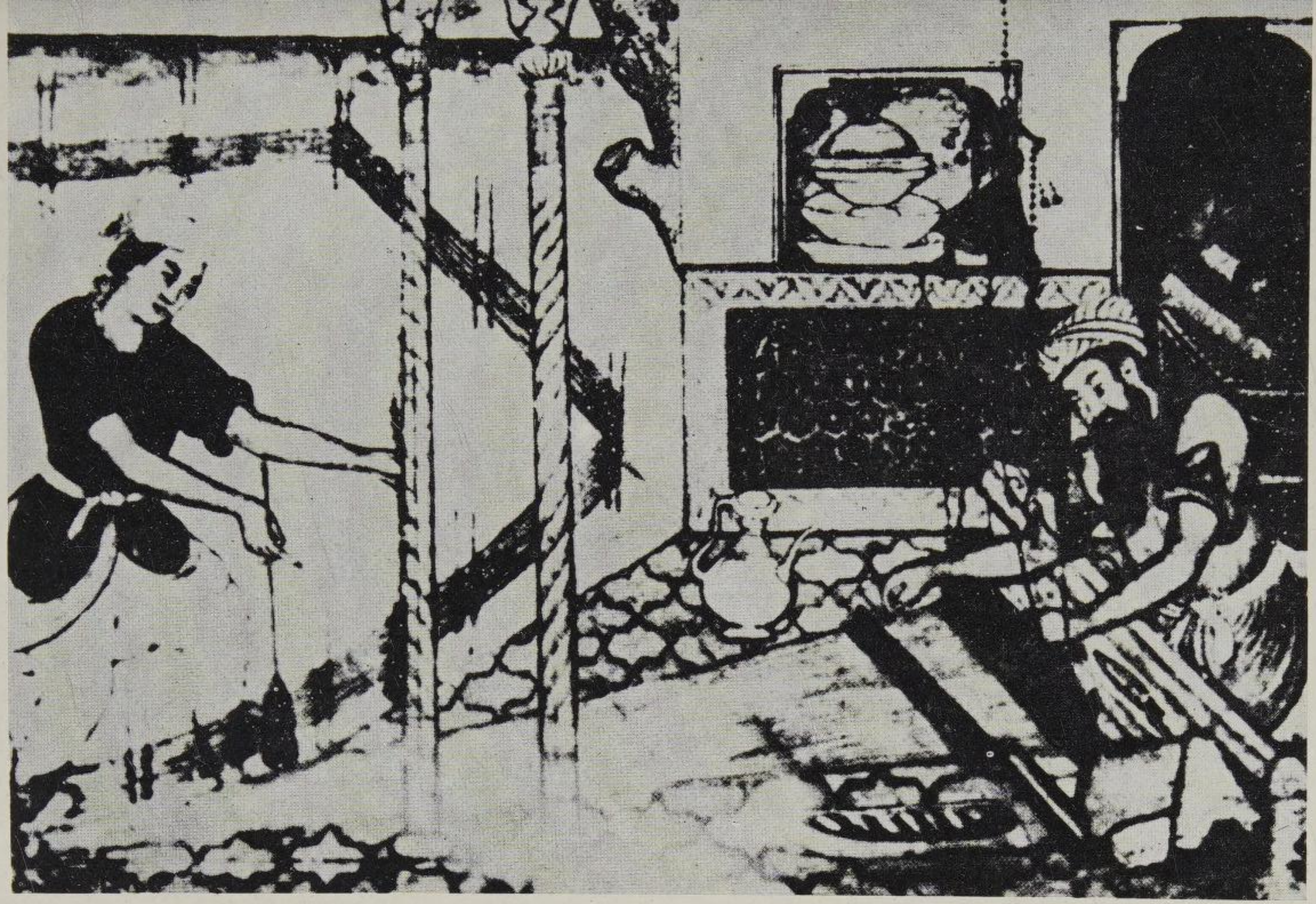

Plate 9. The pit-loom with warp winder at work from *Tutinama (1980-85)*, The Chester Beatly Library, MS. 21, f. 79 r., reproduced in *The Indian Heritage, Court Life and Arts under Mughal Rule* Pl. 23, P. 32 (Zarir, the weaver of silk garments at his loom in Nishapur).

Plate 10. Note especially the beating of cotton with stick at the left corner below, two page spools, the preparation of yawn for dyeing, sizing of the warp and the treadles of the loom, *Johnson Album* 8, No. 5, India Office Library, London, reproduced in T. Falk and M. Archer, *Indian Miniature in the India Office Library*, Pl. 3, Cat.—4, p. 47.

documentary evidence, but the use of the same mechanical principle in the Indian sugar-cane rollers is significant. It can not escape notice that there is no early evidence for worm rollers in any other civilization, and both cotton and sugar-cane were indigenous to India. The main difference between the two kinds of rollers is that in the cotton-gin, rollers are always mounted so as to rotate vertically whereas the sugar-cane rollers move horizontally.

In the cotton-gin, the two oppositely rotating rollers were made to engage by placing the elongated worms side by side.[9]

It is not certain when the *Charkhi* obtained its crank-handle. Documentary references such as in the *Bahar-i-Ajam* (1740) are not helpful[10] But the depiction of the *charkhi* in a miniature Kangra-painting dating back to the mid-18th century,[11] shows the crank-handle. No further mechanical change has been traced during the medieval times.[12]

The Islamic world received the cotton-gin earlier than China[13] for China the first evidence comes from the fourteenth century A.D.[14]

After the cotton has thus been ginned, its fibres need to be separated. Scutching not only loose the texture of cotton, it also removes dirt and dust. One of the most primitive methods for achieving this was beating cotton with stick. A Mughal painting of the late 16th century, 'Idris giving instruction to mankind in the art of weaving', shows the use of stock for beating cotton (*Plate* 10).[15] Even by the 17th century; this mode of scutching cotton was found side by side with bow-string device.[16] But beating

cotton with stick had its own hazards. Instead of loosening, it might break the fibres. Therfore, the bow-string device was much better. The vibrations of the string open up the knots of cotton, loosen and separate of fibres of the plant material instead of scutching where the fibres have to be broken.

There is some dispute about the origin of the bow-string device.[17] The first textual reference to it in India may be traced in one of the *Jatakas* where one reads, *itthinam kappasapothanadhanukam* (*i.e.* a woman's bow for carding cotton).[18] It was apparently in use also in the early centuries of the Christian era.[19]

As mentioned above, Schlingloff indentified a rectangular frame in the ajanta fresco of the mid-6th century with the bow-string device. But a rectangular frame can not produce the required vibration. This is only possible when the frame was bow-shaped for it would then have elementary aspect of a spring in the vibrating wire, for loosening and separating the fibres instead of scutching.[20] In fact, as already shown above, the instrument depicted in the Ajanta fresco was really the *charkhi* which has to have a rectangular frame.

India, thus, had a bow-string device in ancient times at least since 2nd century A.D. It might have diffused among other cultures from India. Irfan Habib finds the earliest evidence for Islamic world's familiarity with it only in the 11th century A.D.[21] China recieved it in the 13th century with cotton itself.[22] It was known to Europe only in the 15th century.[23]

For medieval India, textual references to it have been

traced in two Sanskrit dictionaries of 11th and 12th centuries.[24]

The earliest pictorial depiction of it, however is found in the two illustrations in the *Miftah-ul Fuzala* (*Plates 4 and* 5).[25] Both the bows are identical in shape. Each bow consits of a round wooden bow shaft. The shape of the top of the bow is like a sickle, and the bottom is made by a board which is probably inserted into the slot of a round board carrier and the whole is attached to the shaft. A strong bowstring runs from top to the bottom of the foot-board of the bow. But both the illustrations do not show any toggle-peg which is usually placed between the strings to achieve rough tightening by twisting it. Apart from it, the leathern block between string and foot-board for final adjustment is also absent. A sling of some material (perhaps of cotton yarn) is shown fastened to the bow shaft near its centre of gravity. The bower passes one hand through this sling while working, it also protected his hand. The *Miftah-ul Fuzala gives duruna, shafshahang, lorak and kaman-naddaf* as synonym for the bow-string device.[26]

An important part of the bow-string device is the mallet. The *Miftah-ul-Fuzala* gives the synonym *mushta* (mallet) as *shafshahang*.[27] The mallet is depicted in both the illustrations of the bow-string device.[28] The mallet has double tapering heads. In operation, the bower is depicted as holding it by the middle in his right hand (*Plate* 5). The ridge of the upper head grips the bow-string when the bower strikes the string with the mallet. When so struck, the bow-string becomes very tense and slips off the ridge. This results in strong vibrations, which help to loosen the cotton fibres. The bow-string device still survives practically

as it was in medieval times, the cotton carder being called *dhuniya* in Hindi, the process being called *dhunna*.[29]

Spinning was the next important preliminary process prior to weaving. Spindle has been the basic instrument for spinning yarn in all the cultures prior to the spinning wheel. We do not find its depiction in the paintings of our peirod. It is missing where it could have figured, like in the Ajanta fresco, where a lady is perhaps shown spinning yarn (*Plate* 1).[30] However, Indian archaeologists have found whorls—a supplementary part of spindle—if not spindle itself.[31]

The *Miftah-ul Fuzala* describes *shokak* or *sangok as* the whorl-holder in which spindle (*dusk*) is rotated; the whorl-holder called *phiriki* in Hindi.[32] The *Bahar-i-Ajam* explains *duk* (spindle) as a long (*mustatil*) wood under which another wood is attached and that iron or wood is rotated by both hands, so that short (*khwurd*) silk or wool is twisted (*tafta bashad*).[33] The two bits of wood or one bit of wood and one of iron in this definition refer to the whorl of the spindle containing the spindle, the *phirki* of *Miftah-ul Fuzala*. The whorl greatly increases the speed of the spindle, leading to the more rapid spinning of yarn.

The single-spindle hand-spinning -wheel was a major tool of spinning technology. We have not come across any evidence for wheel-spinning in ancient India.[34] Lynn White was the first to notice the absence of spinning-wheel in ancient India.[35] The spinning-wheel came to India only with the Ghorian conquerors in the 13th-14th centuries.[36] Isami (1350) is the first to refer to it in India.[37] However, the first illustration of it in India could be found in the *Miftah-ul Fuzala*, though the drawing is not very

clear[38] it does not show any crank-handle on the wheel, either on its rim or its face (*Plate* 6).[39] In one of the two spinning-wheels shown in *Harivamsa* (1590-95), the crank-handle is not visible and many well be absent.[40] The depiction of spinning-wheels is an unsigned miniature of Jahangir's atelier, cannot be taken as the representative of their counterpart in Mughal India; the miniature being drawn after the Persian example; but the wheels yet lack handles.[41] Perhpas they were single spindle-hand-spinning wheels. However, three successive operations, *i.e.* spinning the yarn, winding the spun yearn on the distaff and finally the collection of of spun-and-wound yarn, have been shown in this miniature. In another spinning wheel depicted by Bichitr during Jahangir's reign, a half-handle with a hole for a small wooden peg-handle can be seen.[42] A miniature of Aurangzeb's reign (1658-1707) displays a sinning-wheel where a piece of wood mounted on the axle at an angle is visible.[43] This could have been capable of performing the function of crank-handle. Another mid-18th century (1760) painting shows the crank-handle clearly.[44] This suggests that the use of crank-handle in crude form began in the 17th century and sophisticated crank appeared in the 18th century. A further improvement was achieved by fitting a connnecting rod to the crank handle by the mid 18th century.[45] The spinning-wheel seemingly did not receive any further improvement.

The spinning-wheel incorporated power transmission by 'wrapping connection'. It embodied one of the earliest uses of flywheel principle and differential speed of rotation. The belt-drive was essential to the main motion in this tool. The use of belt drive confirms the employment of this power transmission method on production technology as

early as 14th century. The introdution of spinning-wheel enhanced productivity tremendously.

Once the yearn is spun, it has to be transferred to the spool. In the *Miftah-ul Fuzala*, the earliest illustration of this tool could be found.[47] The glossary explains it as "a wooden instrument on which cotton yearn and silk are wound, it is called *pareti* in Hindi."[48]

From the cage-spool or the winding stick, the yarn was taken off as skein. The *Miftah-ul Fuzala* again helps us in understanding this when it describes the *Kalawa* (a skein) thus, 'as yarn is put on yarn, that is coild (*pechand*) and that is called *ate* in Hindi'.[49] This is the earliest and perhaps solitary evidence so far traced of skeining.

Yarn was also collected in the form of coils from the cage-spool for dyeing prior to weaving. This is depicted in a late 16th-century Mughal miniature (*Plate* 10).[50] A man is shown transferring the collected yarn from the cage-spool on to the wooden pegs driven into the ground in a circular manner. The coiled yearn could be then collected and dyed.

Collection of yarn on the weft-spool to be used in the shuttle was also a very important process prior to weaving. For weaving, the yarn is wound from the skein on a reed. The reed was pushed over the spindle head and the yarn was wound from skein on to the reed which served as the weft-spool. In an illustration the *Miftah-ul-Fuzala* has tried to show this, but the drawing is not very clear (*Plate* 6)[51]. Here we find the ancillary use of spinning-wheel which raised productivity considerably by being of use also in preparing the weft-spool in a shuttle, a job which

was done by some other process until the introduction of spinning-wheel. The *Miftah-ul-Fuzala* has made the task of interpretation easy by explaining the whole process. This is the earliest reference to it. *Zaghuna* was the obsolete word for it, and *mashora* was the word in use. Our lexicon describes the weft-spool (*mashora*) as "yarn (risman) which women arrange (*sazand*) in the shape of an egg on a spindle."[52] He also describes it elsewhere, where he says: "Yarn is straightened (*rast kunand*) and yarn is put together (*baham karda*)".[53] The *Bahar-i-Ajam* gives a more accurate definiton and also related it to further process in weaving. It describes, "*mashora* as is that on which weavers would yarn, pass (*guzarand*) it into the shuttle (*maku*)".[54]

Warp-winding was the next most important process prior to weaving. Warp winding in its simplest form is shown in a Mughal miniature in the manuscript of Ziauddin Nakshabi's *Tuti-Nama* (1580-85), where the weaver of silk garments has been shown at his loom (*Plate* 9).[55] A man is shown transferring the collected yarn from warp winding stock on to a number of warp pegs driven into the ground in circular manner. Two pegs could be seen placed near each other possibly to achieve a warp-cross. First, the warp winder attached the end of the thread to the first warp peg and then carried on the business of passing the thread to the right and left of the cross pegs alternately, until the warp has the requisite number of threads.

In order to facilitate weaving, warps were sized to reduce friction and avoid damage to the threads during weaving. The *Miftah-ul-fuzala* describes size (*ahar*) thus: "it was *bat* or *pat* (size) that was put on the cobweb (*tansta*)

of yarn".[56] The description is accompained by an illustration of yawning and stretching (*Plate* 7).[57] The yarn is put horizontally and is supported at both ends by stout sticks driven into the ground. A man is depicted applying the size on the yarn with a brush (*mala*). Our lexicon also describes the brush (*mala*) as à weaver's brush (*sima*). by which a weaver puts size upon yarn of the cloth; this is called *kunchi* in Hindi.'[58] This is also clearly shown in the late 16th century Mughal miniature (*Plate* 10).[59]

The process of weaving consists of interlacing at right angles the two series of threads, the warp and the weft; the instrument by which this was done was the loom. The Indian weavers normally used the horizontal throw-shuttle type loom for the simple or tabby weave. While this loom is very ancient, the pai of treadles where with the sets of warp threads are lifted or depressed to allow for the shuttle to pass through, are thought to be a late addition.[60]

The earliest evidence for the use of treadles in India comes from the 15th century. The *Miftah-ul Fuzala* provides an illustration depicting treadles (*Plate* 8). It defines *lauh-pay* (*lit.* foot-board) as the wooden strip which the weaver keeps under his feet while weaving cloth.[61] (*lauh pay: Baby parsi takhta kah julah zirpay wa jama bafad*).

The pit-loom is first depicted in the Mughal miniature in Ziauddin Nakshabi's *Tuti-Nama* (1580-85) (*Plate* 9).[62] In the loom the pair of tredles is usually placed in a pit in the ground. The weaver operates while sitting on the edge of the pit. The treadles are clearly depicted in the late 16th century Mughal miniature (*Plate* 10).[63] They are further attested by the 17th century depiction of the weaver saint, Kabir.[64]

It is possible that the advent of the treadles in India had the same source and possible approximately the same date as the spinning-wheel, datable to the 13th-14th century; but this remains a matter of speculation. Whenever the improvement might have occurred, its effect must have been very great, because it radically increased the speed of weaving; the hands would be freed to manipulate only the shuttle and beater-comb, while the feet previously left idle, would work the opening and closing of the shed.

In all these paintings, warp is displayed straigthened horizontally. In *Tuti Nama* miniature,the warps beam is missing. Instead, one finds a continuous flow of cross warps which a man is busy in arranging (*Plate* 9).[65] But in the late 16th century painting warp beam is clearly depicted (*Plate* 10). It is further tightened by tying it to a thick wooden peg. The warp tying string is shown near the breast beam. Perhaps, the weaver loosened it to the bring the unfinished warp threads near him.[66] Other components of loom like rod heddle (to which the odd threads were lashed to lift half the threads to create the shed), shed rod (which was drawn close to the weaver when the heddle rod was let down from its suspension to form counter shed for the passage of next weft); are clearly depicted (*Plate* 10).[67]

Fancy or complex weaves naturally required much greater manipulation in order to obtain the insertion of threads of various colours in the weft. Indian weavers had apparently developed the *patola* fabric by the 1st century A.D., for Moti Chandra introduces us to *vicitra-patolaka* (variegated *patola*) in the *Lalitavistara* (1st century A.D.)[68]. *Patola* also occurs among species of valuable fabrics

obtained by Alauddin Khalji from Deogir.[69] It seems that *patola* was a particular fabric of Gujarat town of Patan,[70] although owing to the antiquity of the term, the similarity in names is totally accidental. *Patola* is essentially a simple weave; it is the warp and the weft which are pre-dyed in sections to proceed designs. In it, therefore, both sides exhibit the same pattern as against complex weaves with threads each entirely of one colour where the two sides must be different from the other.

A pattern achieved through complex weave demanded a different weaving technique than either for tabby weave or its *patola* variation. This was achieved best of all in the draw-loom. The draw-loom multiplies the number of sheds which are controlled by cords pulled by a person assisting the weaver. Although figured silks, cottons and brocades of the highest quality were woven in India, it is not certain that ancient India ever had a draw-loom. Vijaya Ramaswamy's suggestion that the draw-loom was known in south India in the 11th century is not based on a clear identification of the term achchutari with the draw-loom since '*tari*' means loom and '*achchu*' means mould or print only.[71]

In Iran, the draw-loom is called *dastgah-i naqsehbandi*, *dastgah-i naqshbandi* and *dastgah-i zaribafi*.[72] If *naqshband* means draw-loom weaver, then the draw-loom is as early as the 14th century for Isami (1350) used the term *naqshbandan*.[73] Isami sepaks of the arrival of 'Chinese *naqshbands*' (Chinese pattern weavers) at Iltutmish's Delhi.[74] Later on during Muhammad Tughlaq's reign it is reported that the Sultan had employed 500 manufacturers of golden tissues, who wove gold brocades.[75] In *A'in-i Akbari*, Abul

Fazl refers to a certain Ghias-Naqshband who was an excellent weaver.[76] The use of draw-loom survived into modern times in Indian traditional weaving for we have a clear description of draw-loom in the last decade of 19th century at Murshidabad (Bengal).[77] The Murshidabad loom had a draw harness which operated on the figure warp only. It consisted of a large number of vertical draw-strings. Each draw-string was connected to a horizontal gut string in a cross harness. With the lifting of one draw-string, the cross harness gut string was lifted and with it mails attached to warp threads were raised, the resulting pattern could be repeated. Besides, the reference to the draw-boy sitting on an elevated platform manipulating the draw-strings makes the identification with the draw-loom beyond dispute. Therefore, if *naqshband* distinctly means a weaver working with draw-loom, it could have been indtroduced in India as early as fourteenth century.

It is, however, surprising how limited remained the use of the draw-loom in India.[78]

There is no known archaeological or documentary evidence for cloth-printing in ancient India.[79] There is a reference to an 'instrument' (*yantraka*) in a 12th century work *Manasollasa*, with reference to dyeing which iduces Vijaya Ramaswamay to argue in favour of the existence of cloth-printing in south India in the 12th century.[80] However, the *Manasollasa* merely refers to the 'material coloured by a tool'. But the patterns described in the precedent and subsequent passages do not warrant the use of printing-block proper.[81] Moti Chandra's supposition of cloth printing in 10th and 11th centuries is also not very convincing.[82] Persian sources of the Sultanate period do not refer to

cloth-printing.[83] Moti Chandra, however, explains the word *chhimpaka* for a female calico printer and *chhipa* for a calico printer of 14th and 15th centureis respectively.[84] Jaisi (16th century) does use the word *chapa*.[85] Surprisingly enough, Abul Fazl does not refer to this process in the *A'in-i Akbari* wherein listing various kinds of textiles, he could have mentioned it.[86] This is not very material, since the author of *Ma'asir-i Rahimi* (1616) extols certain persons for designs (*tarhi*) for *chint* (chintz) made at Sironj, which could only be designs from printing-blcoks.[87] Sironj was a notable centre of chintz manufacture.[88] Thevenot (1666) speaks of printing blocks used for obtaining direct colour impression on cloth in Agra.[89] The use of the word *chit* (Hindi: *chhint*) for calico-printed in Isfahan establishes India's primacy in cloth-printing.[90] Tahir Wahid, a 17th century poet, says, 'My lifeless body gets life from the *chit* makers by being used as printer's blcok.[91] He also refers to the appropriate Persian word *qalib* while praising the chintz-makers of Shiraz he says, 'One cannot pass him casually; for in his printer's block (*qalib*) is the soul of a fairy'.[92] In the *Bahar-i Ajam*, the *chhapa* is considered to be a Hindi word for the printing block, said to have been adopted 'recently' as *Chapa* in Persian.[93] The use of the Indian words *chhap* and *chhint* establishes the dominance of India in cloth-printing during 17th century. By 1667, Tavernier reported the decline of calico-painting and manufacturer of large quantities of printed calico for home as well as foreign markets including Persia.[94]

However, a Frenchman George Roque's report on cloth-printing (1678) is the first known source which tells us about the material used in block as well as the technique. He refers to wooden blocks,[95] and writes that the printer

distinguished outlines by the lines and hollow of the first block. After it, another block was used of the same size and pattern. But in place of the raised outlines of the first block, it had a hollow structure. Its voids went directly on the imprint of the first. The remainder of the second block was without engraving to facilitate filling the ground with the desired colour. When the ground was dry, blocks with details of the design were applied in between the black outlines of the first block. After these impressions were dry, another block with 'rays' (radiating lines?) was used, which gave shading to the flower by little lines. These were ordinarily of the colour of indigo.[96]

Thus we find that textile technology witnessed a series of improvements and introductions of various devices during the medieval period. This in turn led to increase in the volume of textile production in medieval India.

REFERENCES

1. e.g., A.P. Usher, *A History of Mechanical Inventions*, Boston, 1959; C. Singer (ed.) *History of Technology*, vol. II. Oxford, 1967; R.J. Forbes, *Studies in Ancient Technology* IV, Leiden, 1964; Lynn White, *Medieval Technology and Social Change*, Oxford, 1962; Hans E. Wulff, *Traditional Crafts of Persia*, Massachusetts, 1966; and J. Needhan, *Science and Civilization in China*, IV (2). 1st pub. 1965, rptd., 1974, Cambridge.
2. cf., D. Schlingloff, 'Cotton Manufacture in Ancient India', Journal of Economic and Social History of the Orient, (JESHO), XVII (I), 1974 p. 89. The cotton-gin is presumably being used here for separating the seed, and the roller-and-board for separating such seeds as may still remain. Or the latter may be used here for separating the fibres ('scutching') in which case the direct conversion to yarn by the spinner becomes explicable.
3. F. Steingass, *Persian-English Dictionary*, New Delhi, 2nd ed., 1981, p. 403 explains the word *chubakin* as a wooden or iron instrument for separating cotton from its seed.

4. Muhammad ibn Da'ud Muhammad ibn Mahmud Shadiyabadi, Miftah-ul-Fuzala, compiled in 873 A.H./1469 A.D., British Library or 3299, f. 100a. Norah M. Titley, who introduces this unique MS of the dictionary, 'An Illustrated Persian Glossary of the Sixteenth Century' British Museum Quarterly, XXIX, London, 1965, p. 18, translates pamba-dana erroneously as cotton-pods; cotton-seed is the correct rendering. In her paper, 'A Note on Textile Crafts Depicted in Indian Paintings', Proceedings of Indian History Congress, (Proc. IHC), 43rd Session, Kurukshetra, 1982, p. 318, my friend M/s Rana Firdaus describes this instrument as having 'two flaps, between which cotton is pressed'. She took the roller for the handle for pressing the flaps together. But she does not notice the transparency of the alleged flaps through which cotton is visible in the figure on f. 100a. Any wooden or metal flap could harldly be transparent. Moreover, an instrument with flaps will only break the seeds after being squeezed in bewteen two flaps.

I am grateful to my teacher Mr. A.J. Qaisar for letting me use his notes as well as photo copies of the illlustrations from the *Miftah-ul Fuzala*.

5. P. Pelliot, *Notes on Marco Polo*, I, Paris, 1949, pp. 501-2; cited by D Schlingloff, *op. cit.*, p. 85.
6. Watt and Murray in *Dictionary of Economic Products of India*, IV, Calcutta, 1890, pp. 152-153, describes a similar process except that it was worked with the worker's feet manipulating the roller. Owing to this, they call it a foot-roller. Sometimes the rod is shorter and slightly conical, in which case the motion is circular. This had an advantage over the hand roller in that the pressure of the feet was joined by rolling motion which certainly increased the rapidity of extraction. One worker can in this way turn out from four to six pounds of cleaned cotton in a day. The feet also do not tire as much as the hands. This can in turn keep the work going on for a longer time.
7. The prevalence of this device in ancient India is best proved by its presence in Cambodia, on whose culture India exercised very powerful influence during the first millenium of the Christian era (Needham, IV (2), pp. 122-124, 204; Since the Indo-Cambodian cultural relationship belongs to the period 5th to 10th century A.D., it is likely that the transmission of this device took place at that time (For Indo-Cambodian contacts

see R.C. Majumdar, *Inscriptions of Kambuja*, Calcutta, 1973).

D. Schlingloff. *op. cit.*, gives its reproduction, p. 89. This has been reproduced in G. Yazdani, *Ajanta, The Colour and Monochrome Reproductions of the Ajanta Frescoes based on Photography*, London, 1930-55, I, PL. XII, text, p. 17. The two rollers, though not visible in the Schlingloff's reproduction, are clearly visible in the Yazdani's.

8. This fresco is in Cave No. I, which dates back to the middle of the 6th century A.D., see M.K. Dhavalikar, *Ajanta-A Cultural Study*, Poona, 1973. p. 2.
9. This device was being in use in China in the 14th century with cotton itself (Needham, IV. (2), p. 124). It is remarkable that the principle of parallel worms did not spread to Europe until 19th century (Needham, IV (2) p. 122).
10. Tek Chand 'Bahar', *Bahar-i-Ajam*, S.V. Charkh. The *Bahar-i-Ajam* seems to give the earliest textual evidence for *charkhi* when it refers to the cotton dresser well *i.e.* cotton-gin (*charkhi-i-naddafi*).
11. M.S. Randhawa, *Kangra Paintings of the Bhagvata Purana*, New Delhi, 1960, p. 50 The cotton-gin is prominently shown on PL. V which deals with 'Migration from Gokula to Vrindavana'.
12. Unlike India, the *charkhi* witnessed improvements in China, in the form of addition of treadle motion to the upper roller besides the hand-crank. This motion was assisted by a radical bob-flyweel. In Japan, the flywheel tended to take the form of a single club-shaped weight attached to the shaft by the early 17th century (Needham, IV (2), p. 123). The Persian gin also shows three rollers and a flywheel, but its first date of use is not certain (Wulff, pp. 179-180).
13. Irfan Habib, 'Technological Changes and Society, 13th and 14th Centuries', *Proc. I.H.C.* 31st Session, Varanasi, 196, p. 145.
14. Needham, IV (2), pp. 122-124.
15. Johnson Album 8, no. 5, India Office Library, London. For reproduction, see Toby Falk and Mildred Archer, Indian *Miniatures in the India Office Library* (Falk and Archer), London, 1981, P1, 3, Cat. 4, p. 47; S.P. Verma has described it in his paper 'Sixteenth Century Mughal Miniatures at the Royal Library '(Windsor) and India Office Library (London)—A Survey of Hitherto unnoticed Paintings', *Proc. I.H.C.*, 42nd Session, Bodh Gaya, 1981, pp. 258-267.

16. *English Factories in India* 1665-1667, ed. W. Foster, p. 174. The cotton was said to be 'bowed or beaten', see also Irfan Habib, "The Technology and Economy of Mughal India", *The Indian Economic and Social History Review, (IESHR)*, XVII (1) 1980, p.6.
17. Forbes, IV, p. 11, traces it to the pre-historic Europe; R. Patterson in c. Singer (ed.) *History of Technology*, II, Oxford, 1967, p. 195, says it arrived in Europe in 15th century.
18. *The Jatakas*, ed. V. Fausboll, VI, London, 1964, p. 41; *The Jataka or Stories of the Buddhas former Births*. tr. H.T. Francis, ed. E.B. Cowell, VI, London, 1957, p. 25. The accurate dating of the *Jatakas* is not possible due to the nature of their compilation. Nevertheless, they are presumably not later than 2nd century A.D.
19. Vijaya Ramaswamy, 'A Note on Textile Technology in Medieval South India', *Proc. I.H.C.*, 40th Session, Waltair, 1979, p. 451; suggests south India's famililarity with this device as early as second century A.D. and certainly not later than sixth century A.D.
20. Needham, IV. (2), p. 127.
21. Irfan Habib, *I.E.S.H.R.*, p. 6; see also, Irfan Habib, 'Changes in Technology in Medieval India' *Studies in History, (S.H.)*. II, (1). Delhi, 1980, p. 17.
22. Needham, IV, (2), p. 127.
23. R. Patterson in C. Singer (ed.) II, p. 195.
24. Moti Chandra, *Costumes, Textiles, Cosmetics and Coiffure in Ancient and Medieval India*, Delhi, 1973, p. 126, cites two Sanskrit Lexicons *Vijayanti* (c. 11th century) and the *Abhidhanacintamani* (c. 12th century) to explain the word *pinjana* as cotton carder's bow.
25. *Miftah-ul-Fuzala* ff. 126b and 259a.
26. *Ibid.*, s.v. durna, *shafshahang*, lorak
27. *Ibid.*, s.v. *shafshahang*
28. *Ibid.*, ff. 126b and 259a.
29. cf. John T. Platts, *A Dictionary of Urdu, Classical Hindi and English*, Oxford, 1960, p. 549, s.v. *dhuniya and dhunna.*
30. See the Ajanta fresco (PII).
31. E. Mackay, *Early Indus Civilization*, New Delhi, 1976, p. 82.
32. *Miftah-ul Fuzala*, s.v. *shokak wa sangok*, f. 188. a-b.
33. *Bahar-i-Ajam*, s.v.*duk.*
34. J. Marshall, Taxila, *An Illustrated Account of the Archaeological*

Excavations, II, Cambridge, 1951, p. 544, took the presence of an iron-axle for the existence of spinning-wheel. But he puts a query which raises doubt even in the mind of Marshall himself.

35. Lynn White, 'Tibet, India, and Malaya as Sources of Western Medieval Technology'. *American Historical Review* LXV, (3), April, 1960, p. 517.
36. Irfan Habib, *S.H.*, p. 21.
37. Isami, *Futush-us Salatin*, ed. A.S. Usha, Madras. 1948, p. 134. Isami speaks of the resentment of the officers of Sultan Razia (1236-40) against her in the following words:

"That woman alone is good, who works all the time with the *charkha* (spinning-wheel); for a seat of honour would deprive her of reason.

Let cotton (*pamba*) be the woman's companion, grief her wine-cub, and the twang of the spindle will serve her well for her minstrel", cited by Ifran Habib, *Proc. I.H.C.*, 1969, p. 142.

38. *Miftah-ul Fuzala*, f. 151a.
39. *Ibid.*
40. S.C. Welch, *The Art of Mughal India Painting and Previous Objects* (Exhibition Catalogue, New York, 1963) P1. 13, p. 164.
41. E. Kuhnel and H. Goetz, *Indian Book Painting from Jahangir's Album in State Library in Berlin*, London, 1926, P1. I, (reproduction in colour of p. 14a of the Album, 'Scene at the gate of a town 1618 (SIC : rect. 1606).
42. Ivan Stchoukine, *La Peinture Indienne a 'L' Epogue des Grands Moghols*, Paris, 1928, P1. XLIV (c. 1620-25).
43. F.R. Martin, *The Miniature Painting and Painters of Persia, India and Turkey from the Eighth to the Eighteenth Century*, London, 1912, P1. 207a.
44. Falk and Archer, reproduce and describe miniature, 'Village Life in Kashmir' (a miniature from Provincial Mughal School namely Awadh), C. 176, P1. 238, p. 435, Cat. 238, p. 137.
45. Lubor Hajek, *Miniature from the East*, London, 1960, Pls. 48 & 49.
46. In Europe, however, the compound crank was developed as early as in the 15th century (Lynn White, p. 113). Moreover, India never received the multi-spindle wheels used in China from 1313 ownards or the U-shaped flyer rotating around the spindle attached to it in Europe by 1480 (Needham, IV, (2),

p. 103 for China and Lynn White, p. 119. for Europe).

47. *Miftah-ul Fuzala*, f. 240a.
48. *Ibid.*, s.v. *Kalaba*. The Hindi equivalent *pareti* is still in use. It is called *pareti* or *phirenti* (Maulvi Zafar-ur Rehman Dehlvi. *Farhang Istilahat-i Peshawaran*, (*Istilahat-i Peshawaran*), II, Delhi, 1940, p. 10, s.v. *parenti, phirenti*).
49. *Miftah-ul Fuzala*, f. 239b. s.v. *Kalawa*. Here again the continuance of the same equivalent upto modern times is very important in understanding the practice of craft (*Istilahat-i Peshawaran*, II, p. 9, s.v. *atti*, or *anti*).
50. Falk and Archer, pl. 3, Cat. 4, p. 47.
51. *Miftah-ul Fuzala*, f. 151a.
52. *Ibid.*, s.v. *zaghuna*.
53. *Ibid.*, s.v. *mashora*.
54. *Bahar-i-Ajam*, s.v. *mashora*.
55. Manuscript in Chester Beatty Library, Dublin. MS 21, f. 79r, for reproduction see *The Indian Heritage, Court Life and Arts under Mughal Rule*, (*Indian Heritage*) Victoria and Albert Museum, London, 1982. Pl. 23, p. 32 ('Zarir, the weaver of silk garments at his loom in Nishapur'; See also the text (pp. 195-6) and fig. (272) in Wulff.
56. *Miftah-ul-Fuzala*, s.v. *ahar*, f 12b.
57. *Ibid.*, f. 268b.
58. *Ibid.*, s.v. *mala*, ff. 27ab, 272a. The Hindi equivalent is still in use in common parlance, with slight modification (*Istilahat-i Peshawaran*, II, p. 83 s.v. *kunch*. It is also called *fuli* or *jhami*).
59. Falk and Archer, Pl. 3, Cat. 4, p. 47.
60. Irfan Habib, 'Technology and Barriers to Social Change in Mughal India'. *The Indian Historical Review*, Delhi, July 1978-January 1979; V. (1-2), p. 164; The treadles in looms were in use in China in the second century A.D. (Lynn White, pp. 117, 173); though they were unknown in ancient Egypt and classical antiquity (Forbes. IV, pp. 214-215). In Europe the treadles began to be used only in the 12th century (Lynn White, pp. 117-118 Lynn White thus corrects Usher, *History of Mechanical Inventions*, Boston, 1959, p. 259; who had suggested a much earlier date).
61. *Miftah-ul Fuzala*, s.v. *lauh-pay*, f. 262a. See also Norah M. Titley, p. 18.
62. *Indian Heritage*, Pl. 23, p. 32.

63. Falk and Archer, Pl. 3, Cat, 4. p. 47.
64. See A.A. Ivanora, T.B. Grek, O.P. Akimushkina, *Album of Indian and Persian Miniatures, XVI-XVIII Centuries*, Akademi of Sciences, U.S.S.R., Institute of the Peoples of Asia, Moscow 1962. p. 66.
65. *Indian Heritage*, Pl. 23, p. 32.
66. Falk and Archer, Pl. 3, Cat. 4, p. 47.
67. It should be noted here that this heddle rod loom was equally useful in weaving carpet and tapestry weaves, irrespective of whether they were horizontal or vertical except the solitary difference of knotting-in a row of piles in carpet weaving (See, Wulff, p. 201).
68. Moti Chandra, p. 30.
69. Zia Barani, *Tarikh-i Firozshahi*, ed. Sayid Ahmad, Bib. Ind., Calcutta, 1862, p. 223.
70. *E.F.I. 1618-21*, pp. 101-2. The name of the manufacturing town is spelt Pattinee' which the editor identifies with Patan.
71. Vijaya Ramaswamy; p. 453.
72. Wulff. p. 206.
73. *Futuh-us-Salatin*, p. 114.
74. Agha Mehdi Husain has translated '*naqshbandan*' as painters in *Futuh-us Salatin or Shah Namah-i Hindi of Isami*, New Delhi, 1976, p. 227.
75. Shahbuddin Abdul Abbas Ahmad, *Masalikul Absar fi Mamalikul Amsar* in H.M. Elliot's *The History of India* III; Allahabad, n. d. p. 578.
76. Abul Fazl, *A'in-i Akbari*. ed. Blochmann, Bib. Ind. I Calcutta, 1866. p. 82.
77. Nitya Gopal Mookerji, 'The Silk Industries of Moorshedabad', *Journal of Indian Art*, V, London, January 1894, pp. 7-8.
78. Irfan Habib, *I.E.S.H.R.*, XVII, (1) p. 8, cites J. Taylor's account about the use of ordinary horizontal loom to weave flowered cloth by Dacca weavers as late as 1800 and Moorcroft and Trebeck's description of Kashmir's shawl weaving loom which had nothing in common with the draw-loom.
79. *Ibid.*, p. 9; see also my paper, 'Cotton Technology in India to the 16th Century, read at 43rd Session of *Indian History Congress, Kurukshetra* 198f, pp. *The Cambridge Economic History of India* c., 1200-1700. Orig. Pub. Cambridge. 1982, reptd. Delhi March 1984, p. 80.

80. Vijaya Ramaswamy, p. 455.
81. *Manasollasa of King Some'swara*, (ed.) G.K. Shrigondekar, II. Baroda, 1939, p. 89.
82. Irfan Habib in *Cambridge Economic History of India*. I, p. 80.
83. *Futuhat-i-Firozshahi*, the term *ehattah* has been used in the context of abolition of certain taxes by Firoz Shah Tughlaq (Firuz Shah Tughlaq, *Futuhat-i Firozshahi*, (ed.) Shaikh Abdur Rashiq, Aligarh, 1954, p. 5.
84. Moti Chandra, pp. 147, 168.
85. *Ibid*., p, 179.
86. *A'in-i Akbari*, I, p. 99.
87. Abdul Baqi Nihawandi, *Ma'asir-i-Rahimi*, ed. M. Hedayat Hosain, Calcutta, 1931, III (2). pp. 986. 1658-9.
88. *Ibid*.
89. Thevenot, Account of India. tr. Lovel (1687), rptd. *Indian Travels of Thevenot and Carari*, Sed. S.N. Sen. New Delhi, 1949, p. 51.
90. *Bahar-i Ajam*, s.v. *chitsaz chitqar*.
91. *Ibid*.
92. *Ibid*. s.v. *qalip* 93. *ibid*. s.v. *chapa* Qalib is the appropriate Persian word.
94. Jean Baptiste Tavernier, *Travels in India*, tr. V. Ball, ed. W. Crooke, London, 1925, 1st Indian ed., New Delhi, p. 4
95. Quoted in Paul R. Schwartz; *Printing on Cotton at Ahmedabad in India in* 1678 (Museum *Monograph*, No. I, Ahmedabad, 1967, p. 8.
96. *Ibid*., pp. 7-8.

6

Capacity of Technological Change in Mughal India

IRFAN HABIB

I

The well-known Sanskritist P.K. Gode initiated researches in medieval Indian technology with his learned papers on such varied themes as distillation, gunpowder, nut-cracker and women's nose-ornament. Since then our knowledge has expanded considerably, though Gode set a standard of critical scholarship which all of us would do well to emulate. The enterprise of the Birla Museum in holding a separate conference on Medieval Technology, along with a splendid exhibition, enables one to take stock of the information so far collected and to raise some preliminary questions.

To begin with, one must always remember that our 'medieval' period in its later part corresponds with the tempestuous developments in European technology during the 15th-17th centuries, preceding the Industrial Revolution. This correspondence in time inevitably excites one's curiosity as to whether medieval Indian technology displayed at any time or in any sector either a comparable

innovativeness or a capacity to accept technological developments achieved in the west. The latter is easier to study since our knowledge about important European inventions is almost definitive, and it is a relatively simple matter to find out whether the European devices are found in Indian technology or not. The internal technological changes are very poorly documented in comparison; but we can perhaps test the society's capacity for change by asking whether a mechanical principle made use of the device in one sector remained isolated there or was diffused among other sectors. Isolation would argue for a very slow changing technology, while diffusion would reflect one in which changes could be rapid.

It may be stated with some confidence that most of the crucial technological innovations of early modern Europe (15th-18th centuries) involved the various combinations of certain distinct mechanical principles, such as gearing, belt-drive, screw, treadles, crank, and springs along with heavier-power-drive. It may be best to review the extent of use of these elements in medieval Indian tools with a view to establishing both the degree of inter-sectoral diffusion (showing the capacity for internal change) and that of simple diffusion of imported devices (showing the capacity for absorption).

Gearing

Gears are an important means of changing the direction and/or speed of motion. In pre-modern India, two forms of gearing were known: worm-gearing and pin-drum.

On the available evidence, which is not large, the parallel worm seems to have been an Indian invention.

Needham recognizes Indian precedence in this device which ultimately led to the rolling mill in European technology.[1] The parallel worm appears in India in the wooden cotton gin, whose Indian origins are established by its presence in Kampuchea (Cambodia) which could only have obtained it from India well before A.D. 1000. The second device in which the worm is found is the sugar mill with wooden rollers. In 1695 Careri saw at Bassein:

> "Sugar Cane's Press'd between two great wooden Roulers turn'd about by Oxen, whence they came out thoroughly squeez'd"[2]

Nineteenth-century British reports show that the wooden rollers were used for milling sugar in Gujarat, Deccan and Southern India, while the cruder mortar and pestle prevailed in the Gangetic basin; the two devices co-existed in Bengal and parts of central India.[3] In the north-west (Punjab) an important innovation had been made by combining the rollers with pin-drum gearing so that cattle could be used to drive the more efficient horizontal rollers.[4] This unique innovation however remained confined to the Punjab, because the use of right-angled gearing itself remained geographically limited within India.[5]

Gearing of this kind was found pre-eminently and, but for the punjab version of the sugar mill, exclusively in the *saqiva* or the persian wheel. There is no doubt that this form of gearing originated in the Mediterranean world in the early centuries of the Christian era, if not still earlier,[6] but the earliest firm description of the gearing mechanism in the water-lifting device in India is in Babur's memoirs (early 16th century). Thereafter it is abundantly pictured

in Mughal miniatures. The gearing was naturally of wood, and this set limits to its efficiency in areas where, the water-table being higher, alternative devices were employable. This, however, cannot explain the absence of the use of the geared wheel in the Deccan and south India, in the drier parts of which it could have been profitably used.

Still more difficult to explain is the absence of pin-drum or any other form of gearing in any other apparatus. Right-angled gearing is a favourite with al-Jazari (1204-6),[7] and occurs in many inventions which Abul Fazl (fl.1595) ascribes to Akbar in his *Ain-i-Akbari*.[8] But neither in Iran nor in India does this form of gearing make its appearance in any tool of the craftsman.[9] It was never made in metal and was thus not given a smaller and more manageable form at all. Forms of gearing after European examples were thus not adopted in India till well into the 18th century at any rate.

Belt-drive

The earliest use of the belt-drive is found in the spinning wheel, whose entire ancient history belongs to China, not India. In India its presence is established by a reference in Isami's *Futuhu-s-Salatin*, which was composed in 1350. There is no proof that it was known in ancient India. But by the Mughal period the spinning wheel was the usual possession of a poor home, as can be seen in Mughal miniatures (notably in Bichitr's famous 'Blind Singers by the roadside')[10].

The belt-drive can greatly accelerate motion; and it could, therefore, be a very efficient substitute for the bow-string used to rotate drills since classical times. yet this

substitution in India came very slowly. Mughal miniatures continue to picture the bow drill;[11] and it survived till modern times in the jeweller's equipment as well as in that of the carpenter and the blacksmith. Nonetheless by the 17th century the belt-drive was in use in diamond-drills which needed much greater acceleration than ordinary drills. But even so, the Indian 'diamond-cutting mill' remained backward compared to the European, because, as Taverner points out, the larger wheel was not yet large enough.[12]

Screw

The threaded screw, as a metal-fixing device, dates in European technology from the middle of the 15th century. Once in use, it contributed greatly to the sophistication of instruments by replacing soldering, rivets and wedge-fittings; it also called forth the development of powerful lathes to cut grooves on the screw.

The principle of the screw, especially for use in locks, was apparently adopted in India. The screws were however, made quite differently, the grooves being obtained not by cutting the metal, but by soldering wire on the metal surface.

> "The Indian of Dehly", says Thevenot (1666), "cannot make a Screw as our Locksmiths do; all they do is to fasten to each of the two pieces that are to enter into one another, some Iron, Copper or Silver wire turned screw-wise, without any other art than souldering the wire to the pieces."[13]

Hans Wolff describes exactly such a screw in Persian metal locks.[14]

Obviously such a screw could hardly serve the various purposes that the European screw could; and its capability as a metal-fastener must have remained extremely limited.

Treadles

Treadles are essentially levers operated by the feet. In China they have been ingeniously used in many devices since ancient times. But in Indian technology their use seems to have been very sparing. They are universal, however, in the weaver's loom, where their use is described as early as the 15th century and is attested to by Mughal miniatures.[15]

Europe too received the treadles originally from China as an appendage to the loom, some time in the 12th century. But the use of the treadles was then extended to other devices: to the lathe (13th century), to the pipe organ (early 15th century), and to the spinning wheel (early 16th century. Such applications never became known in Mughal India.

Crank

Lynn White Jr. assigns exceptional importance to the crank—'next to the wheel'—in the development of machine design. He points to its late appearance in Europe and to the development there of the compound crank from the 15th century onwards.

Indian technology offers a few interesting examples of crank handles as in the cotton gin. The crank handle also appears in a rather crude form in the Mughal painters' depictions of the spinning wheel and in a more refined form in the later Kangra paintings. But no further

sophistication developed, and the use of crank in our craft-technology remained minimal.

Springs

The knowledge of the spring is as old as the bow. So the Hindi term for spring, *Kamani*, from the Persian *Kaman*. Its greatest use in Mughal India seems to have been in locks and muskets (matchlocks). Unfortunately, there is no adequate study yet of either of these manufactures.

So far as we know, the metallic coiled or spiral springs that developed in Europe from about 1400, first for use in locks and then in muskets, were never made or used in India. This was to have fateful consequences, for this placed all items, like clocks and watches (dependent on spring-drive), quite outside the capabilities of the Indian artisan.

Power

India has been exceptionally backward in its use of water power. The only exception has been provided by the horizontal ungeared water mills in use in the western Himalayas which probably received them from the Middle East. Elsewhere, e.g., Malik Ambar's water-mill at Aurangabad, the mills have been mere curiosities. But what is still more surprising is the limited use made of cattle power in Indian craft technology.

The driving of cattle round and round with a radial draw-bar so as to obtain continuous rotary motion may seem simple enough to us today. There is no reason to believe that this was ever done in India before the

beginning of the Christian era; it may well be a Hellenistic importation together with the rotary quern. Once it came, then its use in threshing, oil-press, sugar-mill and water-lift (Persian wheel) was perhaps only a question of time. Yet the use of cattle power did not penetrate many other sectors. For example, in spite of many thousands of coins being daily turned out by each Mughal mint, stamping of the coins continued to be done manually.[16]

The absence of use of animal power in driving bellows was even more serious in its consequences, since good cast-iron can only be produced in large forges or furnaces, given high temperatures by power-driven bellows. Such bellows were in use in China much earlier than in Europe. By 1550 bellows in Europe were being worked 'by trip-lugs on water-driven shafts, or by systems of cranks, levers and weights'. Cuneate all-wood blowers became general by the latter half of the 17th century. But no development over the age-old skin-and-wood bellows occurred in India in respect either of construction or of driving force. Since with such bellows the furnaces could only be very small, large pieces of copper (or bronze) were cast by collecting melted metal from a number of furnaces, a method which made the Indian bronze cannen 'good for nothing', as a European observer put it (1666)[17]. The deficiency was felt still more greatly in iron; and by the 17th century India, which used to export high quality iron and steel earlier, was so far behind Europe that the English factors complained in 1668 of the scarcity of 'Iron Work' in India.[18]

II

Limited as is this survey of the medieval Indian

technology, it does bring out the fact that almost all the principal mechanical elements of the early machine design, except perhaps the valve, are separately present in it.[19] At the same time, each element appears totally separate; combinations which alone could produce machines are extremely rare. Moreover, each element is present usually in one or two devices, but is not found in other crafts where it could have been applied; in other cases still, there are inexplicable geographical limits to diffusion of a particular device. Thus the internal mechanics of technological change, while they did operate, where still extremely slow-moving. Nor did India show any effective response to modern European technology in the 16th and 17th centuries: European tools and pre-industrial machines were not imitated in India: the absence of the true rivetting screw and the spiral spring are symptomatic of the indifference to these critical advances in the West.[20]

Explanations are needed for both the sluggishness of internal innovation and the imperviousness to importation. One major explanation may well lie in the fact that medieval India had developed an exceptional degree of manual skill, which seemed to compensate for the crudeness of implements. "Numerous are the instances", says Bernier (1663), "of handsome pieces of workmanship made by persons destitute of tools . . . some times they imitate so perfectly articles of European manufacture that the difference between the original and copy can hardly be discerned."[21] Fryer (1674), speaking of a Surat coral worker, "wondered (at) the tools he worked with, more than his Art, because we see it surpassed in Europe, but with far more invention of Instruments. Here hands and feet being all the Vice, and the other tools misshapen bits of iron."[22]

Elsewhere, again he says: "And by this small Taste of their unweariedness in Painstaking, their Cheapness of everything and their faring hard, all their other Craftsmen may be valued, who work for nothing comparatively with our Europeans though in many things they exceed them for curiosity, as in staining of Calicuts (Calicoes), and fine work either in gold or silver."[23]

The situation that we visualize then is an abundance of skilled labour, which, owing to low subsistence costs, inhibited improvement in tools. A finer product could be attained more cheaply by a larger application of labour and manual skill than by adopting a mechanical refinement. This would doubtless not apply where, as in liquor distillation (received in India, 13th-14th centuries), the product could not simply be attained by any greater input of labour/skill. In other cases too, where the labour-saving by a mechanical invention could be enormous, the improvement would be cheaper than any possible multiplication of muscle power.

Of this, perhaps, the most outstanding example is calico-printing. The original chintz, Hindi *chhint*, Sanskrit *chitrapeta*, was painted cloth. In the 17th century the Masulipatam artists painted chintz for the world market. But this was a luxury product; there had been a steady substitution of printed chintz for the painted. The printing block enabled the printer, with less skill and labour to produce a far larger quantity of decorated cloth than the painter. It is possible that cloth-printing in India is not older than the 14th century. India is almost certainly the country of its origin, though inspiration may have come from paper printing or inked seals, both diffused from

China by the Mongols.[24] Yet paper printing would not be adopted in India because the scribe would still work cheaply and with much art.[25]

But the outstanding example of the rejection of a labour-saving device because of simple 'skill-compensation' can be offered from the textile industry itself. The drawloom was a device long used in Iran for weaving patterns.[26] But this was seldom adopted in India. To produce their famous flowered muslen, the Decca weavers, working in pairs, labouriously counted the appropriate warp threads and lifted them through the insertion of a bamboo stick at each throw of the shuttle.[27] In Kashmir the weavers resorted to what was in essence embroidery rather than use the drawloom.

Thus one important inhibiting factor was the presence of a relative supply of skilled labour, which Indian civilization had managed to create by centuries of commodity, or market-oriented production.[28] "A good thing in Hindustan", Babur (1526-30) had said, "is that it has unnumbered and endless workmen of every kind." The large population of skilled labour had its corollary in low wages; and in petty production, where the artisan owned his own tools, the pressure of competition compelled him to sharpen his skill, rather than improve his tools on which he could not afford more expense.

The development of skill meant extreme specialization; and India therefore saw a multiplicity of professions which occasioned much surprise to European merchants. Pelsaert (1626) said that there were in Agra:

"Goldsmiths, (calico) painters, embroiderers, carpet-

makers, cotton or silk weavers, blacksmiths, coppersmiths, tailors, masons, builders, stone cutters, a hundred crafts in all, for a job which one (workman) would do in Holland, passes through four men's hands before it is finished.[29]

The picture may be corroborated by Abul Fazl's description of the different occupations within the mint: coin-changers, weighmen, ore melters, gold-plate makers, refined-metal melters, ingot casters, engravers, silver refiners, hammersmiths for refined silver, assayers, gold-separators, and silver separators.[30]

Such specialization was mostly brought about by a socially set division of labour, the caste system. While it helped to increase skill, an improvement in technology could be further inhibited by the barriers of ignorance inherent in the isolation of hereditary castes. "There is a fixed caste for every sort of work and for everything", observed Babur, "which has done that work or that thing from father to son." Max Weber's well-known argument was that since the caste created 'segregation of skills' and prevented inter-craft mobility it would prevent any technological improvement. It may be recalled that in Indian technology inter-sectoral diffusion of particular devices is very rare; and this very closely fits in with the Weberian thesis.

Another argument in Weber is the submergence of all individual ambitions by caste rigidities. Bernier (1663) would have agreed, for he observed that:

"No one (aspires) after any improvemet in the condition of life wherein he happens to be born. The embroiderer,

brings up his son as an embroiderer, the son of a goldsmith becomes a goldsmith, and the physician of the city educates his son for a physician."[31]

A lack of ambition would have prevented any display of enterprise in mechanical innovation.

Morris D. Morris has in an important article challenged the entire Weberian argument.[32] There is no doubt that, over the long run, castes altered their professions and there were fresh entrants into particular professions through the rise of new castes or even assimilation by old castes. Fukazawa tells us of the caste of tailors of Maharashtra, which during the earlier part of the 18th century took to dyeing, while another section of the caste separated to undertake indigo-dyeing.[33] Yet, after all, Weber's argument only stands qualified; it does not totally fall. Caste system has survived because of its capacity to accommodate and adjust to economic change. But since it so closely suited the pressure for skill-specialization in the medieval economy, the hereditary division of labour and the socially set 'segregation of skills' could not but be important negative factors in the development of production technology.

If then there were only limited inducements for innovation within craft technology, the question may be asked whether it could not be externally induced by the higher, non producing classes. The question may be supplemented by an illustration. The Mughal aristocracy had taste for fruits, especially Central Asian fruits. Thus in their orchards they laid out waterworks (with 'Persian wheels'), imported gardeners and seeds, and most important, encouraged the practice of grafting. The quality of the

oranges was very greatly improved in the 17th century; and in the 18th century; varieties of grafted mangoes (initially introduced by the Portuguese with the 'Altonso' in the 16th century) appeared in northern India under similar impulses.[34] Could not improvements in mechanical technology be similarly made where the control over production processes lay with the aristocracy, as in the *Karkhanas* (or workships within the Imperial and aristocratic establishments), or by the merchants when they directly organised production (in their *Karkhanas*, or in mining, ship-building, etc.)?

This raises the issue whether even when directly controlling production, the noble or merchant supplied the tools as well. Marx has given particular importance to the artisan's ownership of his tools pre-capitalist petty production. And it is remarkable how, whatever the form of organisation of production that we find in medieval India, the tools are always those of the artisan: Only the raw material and the place of work, could belong to the employer. Thus Abul Fazl in his detailed accounts of the imperial workships lists minute expenses and costs of the pettiest articles, but there are no expenses shown for tools or implements.

The same appears to have been the case with merchant-controlled production. In the Deccan diamond mines where thousands of miners wer employed (and each employer had 50 to 100 under him), 17th century descriptions show the leaseholders making practically no investments on apparatus, so that even water was carried up by buckets transferred from hand to hand.[35] In the textile industry where the 'putting out' system (both in

material, and money) was in vogue, the looms belonged to the weavers, and neither the Indian merchants nor the English East India Company even concerned themselves with their improvements. The only instances where the quality of loom becomes of concern to the English factors is when a particular width could not be made with the existing looms, and the weavers asked for advances to have broader looms made.[36]

Still more striking was the case with the Indian ship-building industry. From about the middle of the 17th century, Indian ship-builders began at Surat to copy closely the Dutch and English designs of ships, and the results were eminently successful.[37] Nevertheless, not a single European machine or apparatus is known to have been used in that industry. Apparently the carpenters and others went on working with their own existing tools. We therefore see, again, the copying of the product but not of the technology.

In other words, since tools were not yet separated from the artisan, and capitalist relations had not yet developed even in an embryonic form, craft-technology remained outside the scope of externally induced change. However, the very formulation of the problem in this manner makes an opposite question inevitable. Why did not classes which controlled a share in the social surplus enter the productive process and improve technology, as happened in western Europe, from the 16th century onwards?

It must be realized that neither in Europe nor in India in the 15th or 16th century was there any definite inevitability in the process of economic and technological change. There were constraints in the social structure, it

is true, both in Europe (with its previous feudal order, serfs and guild-monopolies) as well as in medieval India. But there was no absolute 'social determinism' operating at any particular point. It was partly, at least, a matter of ideology as well.

III

Cipolla has argued that modern industrial progress "accelerated dramatically when the resouces of craftsmanship were strengthened by the systematic application of scientific principles developed by more or less professional scientists."[38] He could have added that this stage was preceded by a much longer one when the 'scientists', or, in fact, the educated gentry turned to the observation of craft-production, scrutinized the various mechanical principles discovered there and then mentally (or on paper) combined and refined them and sought to discover new sectors of production where these could be applied. Agricola in the 16th century is justly supposed to represent the model combination of observation, analysis and generalisation in his work on mining and geological technology. It is true that the application of 'scientific' designs to craft technology were not direct or simple matters of transmission from paper to wood and metal. Inventions, to become economically viable, had to wait for favourable circumstances.[39] But there is no doubt that actual production technology in western Europe began to receive scientific influences from the 16th century onwards, and a two-way relationship between craft technology and theoretical science continued to get closer until the Industrial Revolution at last created the conditions for their merger into a practically single system.

In ancient India production technology was apparently not brought into any recognisable relationship with theoretical science. Bhoja's fanciful devices, often difficult to interpret, seem totally divorced from any association with practical technology, let alone the productive process.[40] A different attitude prevailed in another early source of world culture, the Hellenistic Mediterranean, which produced Archimedes and, in its Roman incarnation, Vitruvius. Since Islam in the first two centuries of its existence (7th and 8th centuries) inherited a large part of the Hellenistic sciences through Byzantium, it is important to ask how far Islam was able to bring to India any closer interest in technology. Islamic interest in technology seems to have reached its apex with al-Jazari (1204-6), whose work can now be studied with the help of an annotated translation illustrated by accurate reproduction of the MS diagrams and figures of the contrivances.[41] The Hellenistic influence on al-Jazari is manifest, but the numerous devices in which he uses right-angled gearing seem to derive from his own observation of the *saqiya* (our 'Persian wheels'); so also has the watermill led him to water-driven clock work.[42]

But al-Jazari had no successors, only copyists and plagiarists. This was not surprising since around that time science received a setback throughout the islamic world, its last great representatives being Bu 'Ali Sina (Avicenna, d. 1037), Alberuni (fl. 1030) and Ibn Rushd (Averroes, d. 1198). There was a heavy onslaught on reason (*ma'qulat*) and philosophy (*falsafa*), in which Ghazali (d.1111) played an important part.

In medieval India, therefore, Islam was received when

the scientific tradition in it was in the process of decay. Abul Fazl at the end of the 16th century was to mourn:

> "the blowing of the heavy wind of *taqlid* (tradition), and the dimming of the lamp of wisdom. Of old the door of "how" and "why" has been closed; and questioning and enquiry have been deemed fruitless and tantamount to paganism."[43]

Abu'l Fazl; who was Akbar's minister and theoretician, was at least himself an exception to this traditionalism. He emphasized his respect for the Hellenistic sciences and cited the classical islamic rational philosophers. He was the first to describe scientifically the method of liquor distillation in India, if not in the Islamic world.[44] He also exalted the contrivances ascribed to Akbar, the importance of which especially lay in that they were supposed not to entertain but to do down-to-earth work, such as cleaning gun-barrels, grinding corn or lifting water.[45] Here the right-angled gearing was of the *saqiya* kind. But Abul Fazl insists that there were innovations too in the manufacture of guns and muskets, which clearly derived from Europe.[46] In chemistry there was the invention of water-cooling through use of salt-petre, which seems to be independent of any discovery made in Europe.[47]

These achievements are impressive, not so much because of their substance as of the spirit that they point to. But the spirit was confined to the court and there too it soon died. It had from the beginning perhaps a religious basis, in that the tolerance of science stemmed not so much from a belief in reason as from a belief in Pantheism, which taught one to respect diversity. Ever since the time the doctrines of Ibn al-Arabi (d. 1240) had reached India

(c. 1400). Pantheism had begun to exercise a powerful influence on the Muslim mind, and Akbar appealed to it expressly to justify his religious policy and claims to be the vicegerent of God on this earth. Thus the apparent revival of science at Akbar's court was not backed or reinforced by any general system or systems of rational philosophy.

Moreover, the aristocracy retained a scornful attitude towards the ordinary people. A horror of the common man obtaining education was shared by every one, from Akbar to his bitter critic Badauni. The emperor approvingly quoted the action of Shah Tahmasp in punishing an attendant who supplied a portion of a verse the Shah had forgotten.[48] This attitude made any interest in the technology used by the common man still more remote. The Mughal Empire has produced not a single worthwhile text on crafts or agriculture, how many volumes of poetry or histories it might have to its credit.

The Indian rulers' refusal to respond to western science and thought was thus at par with their indifference to technology. Both added up to an enormous intellectual failure of the ruling class. That failure must always be assigned its due share of responsibility for what did not happen in India—a quickening of technological change even remotely reflecting, if not independently corresponding to, the accelerating progress of Europe.

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15. The treadles *(lauh pay)* are described in the 15th century dictionary *Miftahu-i-Fuzala*, British Library MS. Or. 3299. f. 262a. The illustration of the loom-treadles on the same folio belongs to the 16th century, when this MS was apparently written and illustrated. For Mughal paintings of the treadle-loom see S.P. Verma, 'Sixteenth-century Mughal miniatures at the Royal Library (Windsor) and India Office Library (London) paper presented at the Indian Histroy Congress, Bodh Gaya,

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18. W. Foster, *English Factories in India*, 1668-69, p. 65.
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35. See Methwold in *Relations of Golconda in the Early Sixteenth Century*, ed. W.H. Moreland London, 1931, p. 32. There is a remarkable anonymous account of the mines in *Philosophical Transatctions of the Royal Society, London*, XII (1976); see esp. pp. 910-11.
36. For such a case at Surat see W. Fostered., *English Factories in India*, 1661-64, pp. 208-9.
37. *IESHR*, XVII (1),p., 15, The capstan and tackle that Bowrey admired on the eastern coast were not a European importation, since, if this were so, Bowrey would have hardly had his curiosity aroused. Moreover capstan and pulley are descirbed and figured in the 14th century *Sirat-i-Firuzshahi*, Bankipur Library MS. f. 104b. But see Qaiser, *op. cit.*, p. 33.
38. C.M. Cipolla, *European Culture and Overseas Expansion*, p. 28.
39. Cf. Maurice Dobb, *Studies in the Development of Capitalism*, London, 1947, pp. 268ff.
40. I rely on the interpretation of the devices given in V. Raghavan, *Yantras or Mechanical Contrivances in Ancient India*, Bangalore 1956.
41. Ibn al Razzaz al-Jazari, *The Book of Ingenious Mechanical Contrivances*, tr. Donald R. Hill, Dordrecht, 1974.
42. Of course, Jazari, was not the first to design such contrivances and could well have had predecessors.
43. *Ain-i-Akbari*, II, p. 3.
44. Ibid., I. pp. 76-77, Cf. R.J. Forbes, *A Short History of the Art of Distillation*, Leiden 1970. p. 54.
45. *Ain-i- Akbari*, I, pp. 126, 199.
46. *A'in* I, p. 125. Cf. *IESHR*, XVII (1), pp. 17-20.
47. *A'in* I. p. 51. Cf. *Studies in History*, II (1) , p. 38
48. 'Auspicious Sayings' in the *Ain-i-Akbari*, Vol. II.

7

Technology in Mughal India Evidence of Mughal Painting

S.P. VERMA

In the reconstruction of the past technologies the primary evidence must be archaeological, that is the actual survival of tools and instruments. Unluckily, 'Industrial archaeology' for the historical period is little developed in our country; and in any case, the survival of wooden material at least is very unlikely. In the absence of the actual remains of tools, pictorial representations must always occupy a very important place. They do so even when they mainly supplement or explain textual descriptions. The importance is still greater, when as in the case of ancient and medieval India, the textual evidence is limited and pictorial representation often constitute our sole evidence in the form of sculpture, forescoes and miniatures. As may be expected, Mughal miniatures offer us the richest fare.

Mughal painter was not, of course, directly concerned to represent technological-devices. These constitute only small parts of the whole compositions. But since the Mughal painter was concerned to fill his picture with the greatest amount of detail, and draw this as far as possible from real life, the total amount of evidence on material

culture that he put down on paper is exceptionally large.[1] A scene set in the country-side might contain the depiction of a cultivator ploughing or irrigating the field, and drawing water from the well; a wayside scene may show a hut with a spinning-wheel hung under the thatched-roof. In a few cases the technological device forms the central theme, where while illustrating a legend or episode, the miniature pictures mirror making or weaving.[2] In other cases the technological device are relevant to the central theme, thus distillation forms part of a drinking scene.[3] ring-dial, astrolabe and sandglass appear with astronomers, [4] depiction of construction of fort or buildings would show masons, carpenters, stone-cutters and ironsmiths with their tools and implements.[5] Besides the various devices, Mughal miniatures also enable us to study the postures and methods of work of artisans of various crafts.

One important exception, belonging to a very early (and possibly pre-Mughal) phase, is formed by the 179 sixteenth century illustrations of the fifteenth century dictionary *Miftah-ul' Fuzala.*[6] Here the miniatures are drawn specifically to illustrate, tools, etc., defined and explained in the dictionary. The accuracy attained is often of a very high order.

Often the miniatures aimed as 'portraits offer us significant information *viz.*, portraits of artists and the scribes depict spectacles.[7] 'Emperor Shah Jahan ready to fire his gun', is the best representation of a matchlock with maximum details; priming-pan, pivoted-cock, trigger, matchcord, fork and so on.[8]

Margin-illuminations are equally important, since these

contain rare representations of book-binders at work, distillation, filtration, astrologers with time-reckoning devices, bow-string drill, mode of paper smoothening, hunters with matchlock and so on.[9]

In Mughal miniatures objects generally appear in direct-view, but diagonal-views are also met occasionally. The colour pigments used in the original paintings are very accurate and help us to identify the material used in making the tools and implements, whether wooden, metallic, clay or stone. Details are faithfully rendered and thus the use of iron-nails, hinges, plates, use of rope in fastening knots, rivetting, sowing of planks, nature of joints (shiplap, tongue-and-groove) are often quite clear in the depictions.

The degree of accuracy in the depictions is the result of artist's skill in drawing; but there were limitations as well. Mughal painters had little knowledge of fore-shortening, linear-perspective and the visual changes taking place after the positioning of the artist (here, eye-level). Angular projections are drawn in a confused manner, as may be seen in the depiction of the crank-handle in a spinning-wheel. The drawing of the spinning-wheel in *Miftah-ul' Fuzala* (folio 151a) shows how the artist by trying to apply two angles of vision has confused in depiction.[10] Here, for example, the axle passing through two vertical posts and a wheel set in between are drawn just flat (*Plate* 1). In other cases, since the painter is concerned usually to portray what is available from the outside only, important part of the devices do not appear. Thus, for instance, the pawl does not come to our view in any of the numerous depictions of the Persian-wheel. This

Plate 1. Illustration from *Miftah-ul-Fuzala*, British Museum, London, Or. 3299, folio 151a.

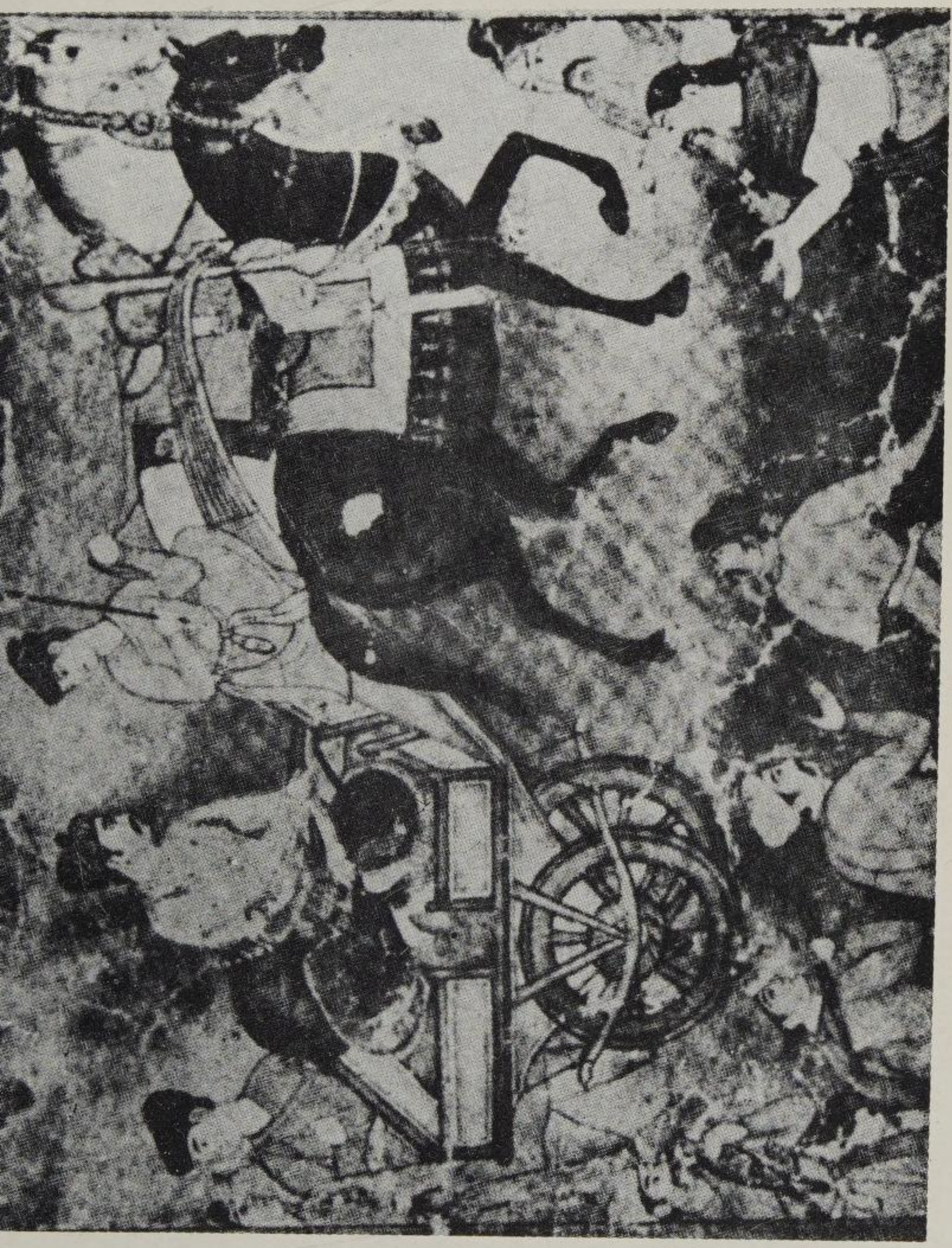

Plate 2. Folio from a manuscript of the *Razmnama*, Sir Cowasji Jehangir Collection, Bombay.

Plate 3. Detail from a miniature, "A camp scene", *Royal Album*, Chester Beatty Library Dublin, Plate No. 11

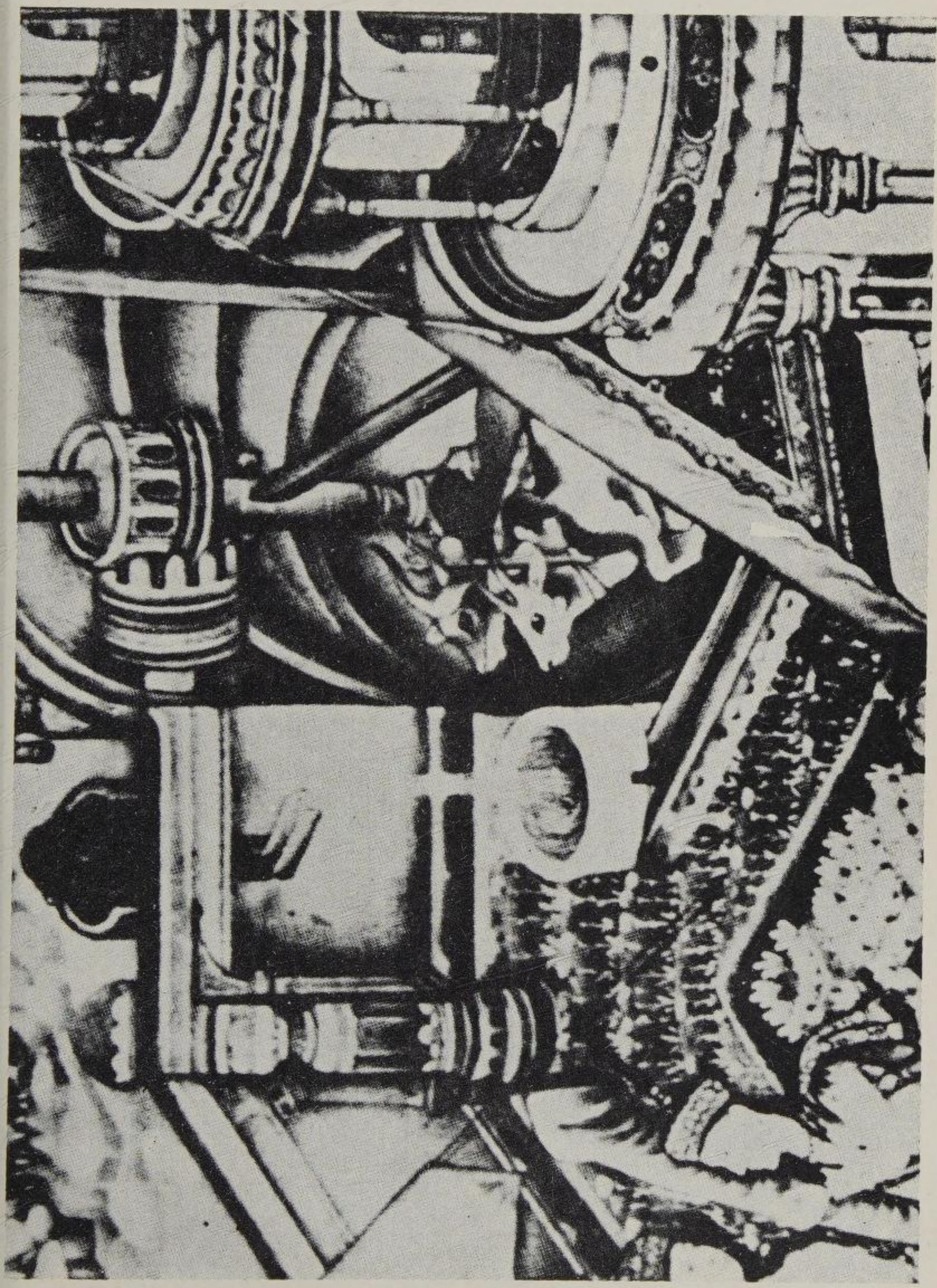

Plate 4. Detail from a miniature in the manuscript *Khamsa*, British Museum, Or. 12208, folio 65a

raises particular difficulty in examining complex mechanisms, such as muskets. One has to look closely at such details as matchcord, pivoted cock, trigger and priming-pan to distinguish matchlocks from handguns.

In some cases the Mughal artist clearly displays his ignorance, *e.g.* in case of horse harness. The Mughal painters continue to depict the horses yoked to the carriages in the same manner as bullocks (*Plate* 2) although it may be presumed that the horse-collar had been introduced in India by this time by the portuguese and the other Europeans who brought in European horse-carriages.[11] In only one rare depiction of early seventeenth century, is the horse-carriage shown without a yoke the shaft of the carriage being shown suspended between two horses.[12] In the absence of the breast-strap harness of collar-harness, the shaft is supported on a horizontal bar placed on the fore-part of the saddles (*Plate* 3).

In general, the original scale of the Mughal miniatures (manuscript-painting and album pictures) is small and the devices being depicted in them are obviously too small; but the clarity in details achieved by the Mughal painters is so great that one can easily identify the details and reconstruct the original devices.

The Mughal miniatures are thus rich for any study of the material-culture of the time, but they do not still cover the full range of the medieval Indian technology, nor tell us what was not there. Yet the following important mechanical principles and chemical processes are illustrated: pin-drum gearing, crank-handle, bow-string device, bellows, screw, horizontal water-wheel, syringe,

levers and belt-drive, and distillation and filtration, and the use of the sand-glass and spectacles.

While it would take too long to describe all the devices depicted in the Mughal miniatures, an attempt has been made to select, as illustrations, a few important devices of production technology.

We begin, then, with pin-drum-gearing. This is an important component of the water-lifting machine now called Persian-wheel. Numerous depictions of it are seen in Mughal paintings, the earliest of these belong to the MS *Khamsa* (BM, Or. 12208, d.1596)[13]. Many details given in the drawing of Persian-wheel are important since textual descriptions as of Babur and Sujan Rai do not fully explain them.[14] The pin-drum is shown fixed to a vertical post resting on a high pedestal. The top of the pedestal consists of a saucer-like depression in the middle so as to adjust with the lower pyramidical (conical, but rounded at the end) end of the vertical post (*Plate 4*). It minimised the friction while the long handle fitted to the vertical post moved in circular motion being drawn by a pair of yoked-bullocks.[15]

The horizontal axle fitted at one end with a heavy round block with projected pegs. These pegs enmesh with the ribs of the pin-drum. The pin-drum was on an axle which had at its other end a large wooden spoked wheel over a well. This wheel had a pot-garland over it, which brought up water from inside the well (*Plate 5*).

The adjustment of the whole apparatus: pin-drum and the axle with the gear-wheel, stand at a height of about 7-8 feet above the ground on which the bullocks move. This

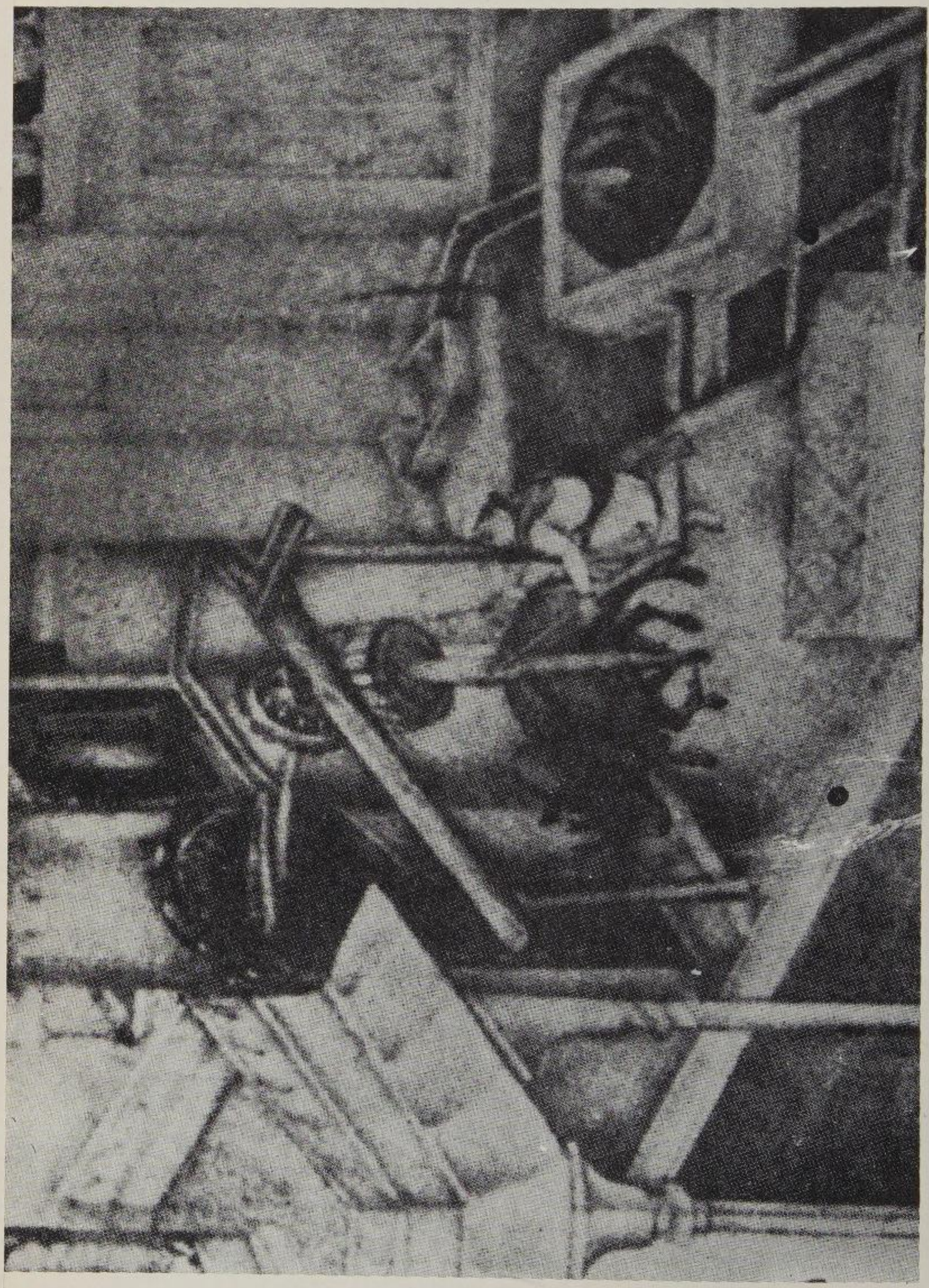

Plate 6. Detail from a minature in the manuscript *Jog-Bashisht*, Chester Beatty Library, Dublin, folio 128b.

Plate 7. Detail from a miniature, "Jahangir playing Holi" in the *Royal Album*, Chester Beatty Library, Dublin, Plate No. 4.

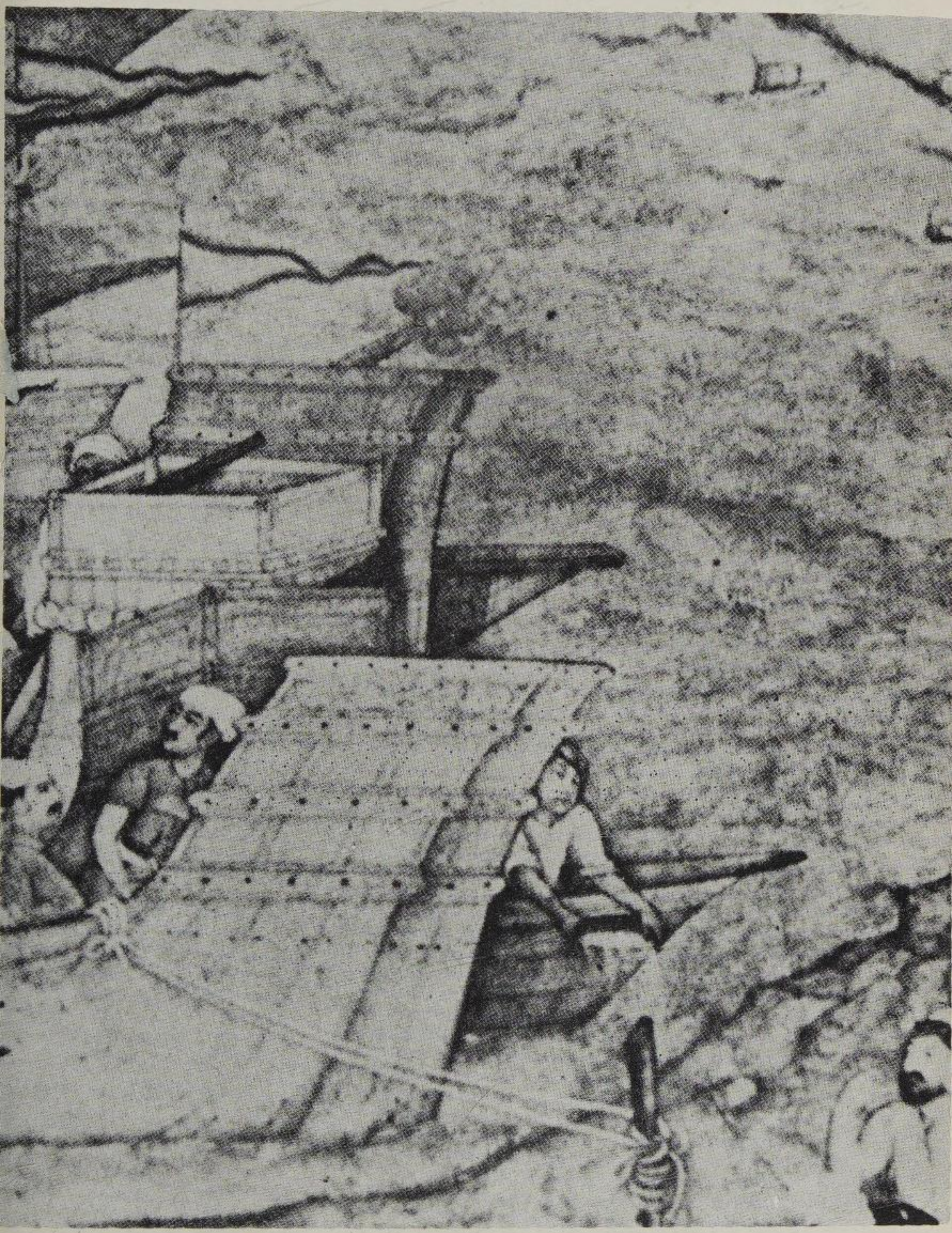

Plate 8. Detail from a miniature, "Assault on Hugli", *Shah Jahan Nama*, Royal Library, Windsor.

enabled the water to be raised to a much higher point than the ground level. It could flow into water-tanks, from which because of their higher level, it could easily reach all parts of the garden.

Another depiction of this device from the MS. *Jog Bashisht* (d.1602) shows a different adjustment of the pin-drum.[16] In it the axle with gear-wheel and the pin-drum fixed to the vertical post is set a little above the ground-level (*Plate* 6). The handle which the bullocks turned in circular motion is fixed quite above the pin-drum. This form of the device is also depicted in the miniatures of the later period (c.1610; 1650).[17] This is what the ordinary Persian-wheel looked like. It may easily be inferred that the former type best suited to the palaces, buildings, etc., and the latter for field irrigation.

The whole apparatus appears to have been made of wood. The garland of pitchers made of rope held earthen-pots. It seems that no improvement was made in its shape and mechanism till the 19th century.[18]

The pin-drum-gearing device appears in Mughal miniatures solely in depictions of the Persian-wheel only during the medieval-period. The only exception is the diagram for the gun-cleaning machine in early MSS of the *A in-i Akbari*.[19]

Various devices of 'pushing mechanisms' are depicted in the Mughal paintings. These are bellows, syringe and water-mill.

SYRINGE

Its depiction appears in a miniature of early seventeenth

century representing women with metal squirts, playing Holi (*Plate 7*)[20]. It worked on the principle of cylinder-and-piston: the piston, working in the cylinder, created a vacuum. Since the device of piston-and-cylinder did not develop with a valve, its transfer to make a pump remained unknown during medieval period. Absence of a pump to siphon water is clear, while to bail out water from the ships/boats the simple method was to throw water from buckets manually (*Plate* 8)[21]. Qaisar sees probabilities of piston-pumps being used in Indian ships during the second-half of the seventeenth century, but observes that these pumps were borrowed or purchased from Europeans.[22]

BELLOWS

In metallurgy, bellows have significant place. Use of a pair of bellows would provide continuous blast. Mughal miniatures (d. 1595) depict its use in furnace used while making a metallic-mirror.[23] The bellows are made of skin-bags with a delivery tube at the bottom-end connected with the furnace sideways. Opening of the skin-bag consist of two clippers (wooden) to stop the air to be pumped into the furnace (*Plate* 9). These bellows may be placed together with the most ancient type of bellows in China.[24] Gold and copper-smiths used an iron-pipe to blow on the fire. This iron-pipe is made tapering gradually towards the end to make the opening narrow. This kind of pipe is illustrated in Mughal painting.[25]

WATER-MILL

Water-mills were a great rarity in the Indian plains. But

one water-mill is shown in a painting of 1603.[26] It depicts the water-mill (rotary millstones driven by water-power), set on a stream in a hilly country. The mill has horizontal water-wheel (*Plate* 10). This device consists of a vertical axle with its upper end fixed in the middle of the upper milling-stone of the flour-mill. The lower end consisted of long flat projections around it (to form the water-wheel). These projections being constantly pushed onward by water, thereby rotating the upper millingstone. The container with an inverted cone feeds the grain into the mill.

While the inner mechanism of the rotation of the millingstones is not shown in the depiction, any possibility of 'gearing' is ruled out since the water-mill does not involve any conversion of vertical into horizontal motion or vice versa. The power obtained must, of course, have been very limited since gravity could not be harnessed to increase the force of water. The water-mill shown in the miniature is found to be closely similar to the water-mill earliest depicted in a painting from Nung Shu (China), dateable early 14th century.[27]

The mortar-and-pestle device for milling and crushing seems indeed to have been wide spread in medieval India.[28] It occurred in the oil and sugar-press. A depiction of the sugar-press is found in the MS of *Shah Jahan Nama* (d. 1657)[29]. It shows three sugar-presses in an open field in separate enclosures. A long wooden post (pestle) loosely fits the deep cavity in the stone mortar fixed on the ground. A handle attached to the pestle is moved in circular motion by one or a pair of bullocks. The cane has to be cut into pieces before being put into the mill; and this

Plate 9. "Making the mirrors", *Khamsa*, Walters Art Gallery Baltimor, MS. W. 613, folio 16b.

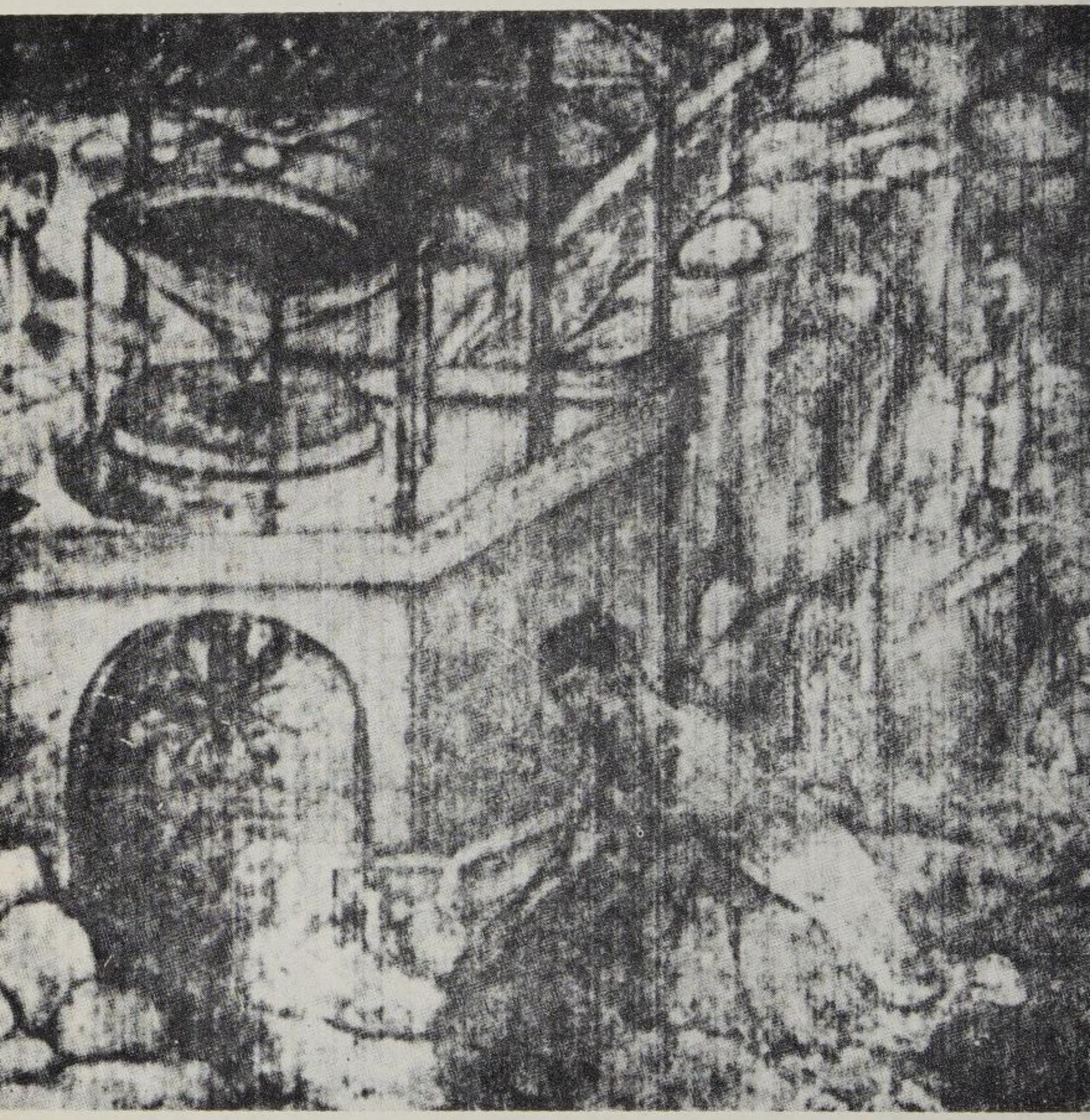

Plate 10. Detail from a miniature in the manuscript *Nafahat ul Uns*, British Museum, Or. 1362, folio 392 b.

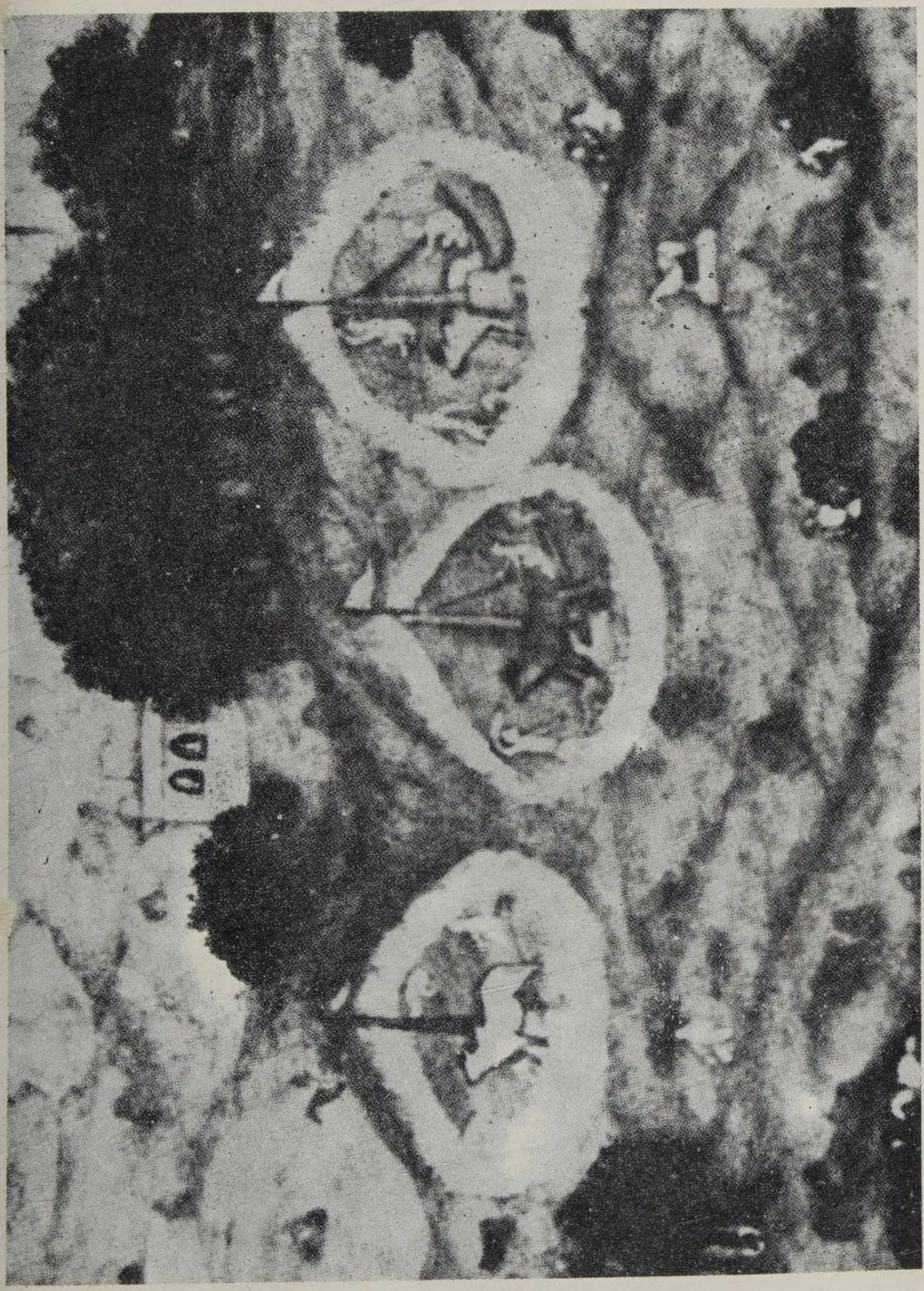

Plate 11. Detail from a miniature in the manuscript *Shah Jahan Nama*, Royal Library, Windsor, folio 165.

Plate 12. "Weavers at work", *Tutinama*, Chester Beatty Library, Dublin, MS. 21, foilo 79a.

is shown as being done in the miniature (*Plate* 11). The mortar-and-pestle sugar-press co-existed in India with the press based on parallel worm (vertically mounted wooden rollers), which is recorded in the seventeenth century[30]. Remains of large mortars with inscribed dated corresponding to A.D. 1553; 1579 have been found.[31]

Amongst the other devices which played an important role in production technology is the 'belt-drive', employed in the spinning-wheel probably introduced in India at the end of twelfth century.[32] In Indian art its earliest depictions are from the Mughal school, in the MSS. *Razmnama* (c. 1582-84) and *Harivansha* (c. 1590-95)[33].

The application of foot levers in medieval India occurs in the horizontal wrap loom, with treadles operated by feet. The treadles are united with levers and connecting rods to lift the warp to form complicated weaving patterns. The lifting of warp-threads through use of treadles greatly quickened the process of weaving. In the depiction of weaving in the *Tutinama* (c.1580-85) levers and connected rods are shown, while the treadles are not visible, the horizontal-wrap loom being the pitloom (*Plate* 12).[34] Another depiction (*c.* 1590) shows treadle (flat, foot-board) being operated by feet (*Plate* 13).[35] But the treadles also appear in the *Miftah-ul Fuzala*, which also contains textual description.[36] However, it is difficult to ascertain the exact period of the introduction of the treadles in India, the pictorial evidence for it that has so far been adduced belongs to the 15-7 centuries, apparently there is yet no earlier documentary evidence.[37] Besides the weaving-loom, the use of treadles did not spread to other devices. Irfan Habib has observed that treadles in lathe and

Plate 13. Detail from a miniature "Weavers at Work", *Johnson Album*, Volume 8, No. 5, India Office Library, London.

Plate 15. Detail from a margin-painting, Naprstek Museum, Prague.

Plate 16. Detail from a margin-painting, Freer Gallery of Art, Washington, D.C.

spinning-wheel never became known in India.[38]

The use of the bow-string device too occurred in the textile-tool, the cardingbow. Carding of cotton was done both by beating it with a stick and by use of the carding-bow. Both methods are illustrated in Mughal miniatures (*Plates* 13 *and* 14).[39] Two types of carding-bows are depicted in the *Miftah-ul Fuzala*.[40]

There was also the bow-string drill. It is depicted in an early 17th century miniature (*Plate* 15). A man rotates with a bowstring the axle of a tool used to polish/cut the precious stones.[41] The textual evidence for this tool belong to 1666.[42]

Amongst the other devices, though important but little known, is the screw. The screw called *'shikanja'* (press), used by the book-binders, is depicted in a Mughal miniature.[43] The tool consists of two parallel thick wooden planks with a pair of holes in both at either sides (breadthwise). Through holes two woodengrooved-pegs pass (to make a screw). The holes in planks too consisted of grooves in the reverse order to that of the pegs. The book-binder made use of this tool to file or press even the sheets placed between the two planks, screwed tight (*Plate* 16). But this conforms to the Hellenistic screw as a pressing mechanism, and is not the modern metallic screw, which is a fastening device as well. Though there is evidence that the metallic screw was being used in locks and Qaisar has noticed it in an Indian incense-burner, there is no illustration of the screw of this kind in Mughal painting.[44]

Other important items illustrative of medieval

technology are the depictions of spectacles, making of mirror, distillation, filtration, matchlock, time-reckoning devices, tools and implements of agriculture, means of road and water-transport, bridges and dams, etc. These too require more exploration.

In general Mughal miniatures attest to what we already know that the level of sophistication in Mughal Indian technology was rather low. The most plausible reason seems to have been the limited use of iron in tools and implements.[45] Secondly, there appears no attempt made to explore various applications of a particular device. An abundant labour and the animal-power being available during the period could also have been the reason for indifferent attitude towards innovation and diffusion of techniques. However, the present survey of the evidence of Mughal painting on Indian technology is provisional, even on the devices described. There is every reason to believe that further researchers can greatly enrich the pictorial evidence on Mughal-Indian technology.

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3. Miniature in *Diwan-i Hafiz*, State Library, Rampur, folio 247 (unpublished).
4. e.g. *Akbarnama*, Victoria & Albert Museum, I.S. No.117, plate 80; *Tarikh-i Khandan-i Timuria*, Oriental Public Library, Patna, folio 284a.
5. *e.g. Akbarnama, op. cit.*, plates 45-6, 86 and 91.
6. The text of the dictionary was compiled in 1460 according to

the preface. It no where contains any reference to the illustrations, which were obviously put in later when the splendid copy in the British Museum Library (or. 3299) was being prepared (for this information I am grateful to Irfan Habib).

Motichandra and Khandalawala were the first to notice its significance and published two of its illustrations on textile and agricultural technology (*New Documents on Indian Paintings*, Bombay, 1969, figs. 129-30; Titley has listed all its drawings in her catalogue, the most significant of them are the textile-tools (carding-bow, spindle, wooden-instrument for spinning raw thread, spinning-wheel with crank-handle and treadles) and agricultural-implements. Other tools and implements of interest are the bow-drill, perforated iron-plate through which gold and silver wire is drawn, wedge, instrument for sharpening millstones, hand-grinder, churning, stone-mortar, whirling-disk, top, swing, etc. (*Miniatures from Persian Manuscripts*, London, 1977, No. 366, pp. 151-54).

For a detailed study of textile tools see Ishrat Alam's thesis "Textile Technology in Medieval India" (Typescript), submitted in the Department of History, Aligarh Muslim University, 1984.

7. See *Jahangir Album*, National Library, Berlin, folio 21a; *Anwar-i-Suhaili*, Bharat Kala Bhawan, Varanasi, No. 9062, folio 242; and miniature in Musee du Lavure, Paris, No. 3.619,1b.
8. *Royal Album of Separate Miniatures of the Mughal School*, Chester Beatty Library, Dublin, plate no. 4.
9. *e.g. see Jahangir Album, op. cit.*, 15b, 18a; Margin-painting in Freer Gallery of Art, Washington, D.C. (detail, n. 24 (below); Margin-painting in Naprestek Museum, Prague detail, n. 40 (below).
10. Unpublished. Mentioned: Titley, *op. cit.*, p. 152.
11. For European carriages see W. Foster, ed., *The Embassy of Sir Thomas Roe to the Great Mogul*, London, pp. 97, 118-9, 320, 322, 347.

See Tuzuki-i-Jahangiri, ed., Sir Sayyid Ahmad Khan, Ghazipur and Aligarh, 1863-4, p. 167.

A'in-i Akbari, tr., Blochmann, Vol. I, p. 285 (*Ain* 28), carriage drawn by horse, camel, elephant, p. 298, cart made for leopards drawn by horse.

But in the Mughal miniatures, leopard is always shown being carried on the cart drawn by bullocks.
The Commentary of Father Monserrate, tr. J.S. Hoyland and S.N. Banerjee, Cuttack, 1922, p. 199. For the information from the *A' in-i Akbari*, I owe to Dr. Shireen Moosvi.

12. Miniature, "A camp scene", Chester Beatty Library, Dublin, *Jahangir Album*, plate No. 11. For reproduction see, Arnold and Wilkinson, *A Library of Chester Beatty, A Catalogue of Indian Miniatures*, London, *op. cit.*, I, p. 30 (11), II, Frontispiece.
13. Miniatures on folios 65a and 99b. Described: Titley, *op. cit.*, pp. 142-43, No. 323. I am thankful to Irfan Habib for kindly allowing me to study the miniatures (photoplates) of this MS., lodged in his library.
14. *Babumama*, tr., A.S. Beveridge, II, London, 1921, p. 486; Khulasatu-t Tawarikh, ed. Zafar Hasan, Delhi, 1918, p. 79.
15. For this detail see miniature on folio 65a (*Khamsa*, BM, Or. 12208).
16. Miniature, "King Janaka listening ascetics in his garden", *jog-Bashisht*, Chester Beatty Library, Dublin, folio 128b. Reproduced and described: Arnold and wilkinson, *op. cit.*, 1, p. 24, II, pl. 49a.
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26. Miniature, "Sarri Sakati watching his child being pulled out of the millstream by its mother", *Nafahat ul Uns*, BM, Or. 1362, folio 392b (d. 1603). Mentioned: Titley, *op. cit.*, p. 69, No. 207. Published; H. Goetz, *Bilderatles Zur Kulturgeschichte Indiens in der Grossmoghul-Ziet*, Berlin, plate 38, fig. 103.
27. Joseph Needham, and Wan Ling, *op. cit.*, p. 369, fig. 621.
28. Irfan Habib, "Technology and barriers to technological changes in Mughal India", *Indian Historical Review*, Delhi, Vol. 5 (1-2), pp. 155-56 ("Yet this mill was the only one used through-out Gangetic plains except parts of deltaic Bengal. It was also in use in Orissa, parts of the Central India up to Khandesh and in Rajasthan").
29. Royal Library, Windsor, folio 165 "From Lahore to Akbarabad (Agra)" (unpublished) I am thankful to the Director, Royal Library, Windsor for providing me the photoplates of the miniatures from this MS.
30. Irfan Habib, "Technology and barriers, *etc.*", *op. cit.*, 156. Here he has described two types of worm press: (a) vertically mounted wooden rolers and (b) geared wooden horizontal rollers.
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    Abu-l Fazl (*A' in-i Akbari*. tr., I, p. 285) mentions of an extra ordinary carriage used for travelling, could be employed for griding corn as well. But no depiction of this novel cart with milling stones is known. Alvi and Rahman in their work have published a modern drawing of it (*Fathullah Shirazi, a sixteenth century Indian Scientist*, Delhi, 1968, p. 7, plate 3).
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35. Miniature, "Idris giving instruction to mankind in the art of weaving" (c.1590) *Johnson Album*, 8(no.5) India Office Library, London.
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See also Lotika Varadarajan, "Medieval indian textile circulation and Techniques" (paper presented at the Scientific and Technological exchanges between Soviet Central Asia and India in the Medieval period—an Indo-Soviet Seminar, held at Bombay, 7-12 November 1981, (cyclostyled copy), pp. 4-5, n.11, where it is said with probability that this innovation may have reached India at an early period.
38. Irfan habib, "Technology in barriers, *etc.*," *op.cit.*, p.164.
39. See miniature, "Weavers at work", in India Office Library (footnote 35, above).
40. BM, Or. 3299, folio 126b (*duruneh* cotten dresser's bow with a mallet); folio 2592 (above) (*lurak*, cotton-dresser's bow). Mentioned: Titley, *op.cit.*, p.152-3, where the drawing on folio 259b reproduced on pl.39.
41. Miniature (Margin-painting) with calligraphy by Mir Ali (in

the middle), Naprstek Museum, Prague.
See reproduction L. Hajek, *Indian Miniatures from the Mughal School*, London, 1960, pl.18.

42. *Indian Travels of Thevenot and Careri*, ed. S. Sen, Delhi, 1949, p.138.

43. See n. 24 above man with *shikanja* (press) depicted in the left hand margin).

44. *Indian Travels of Thevenot and Careri*, *op. cit.*, p. 66; Irfan Habib, "Technology and Barriers, *etc*, *op. cit.*, p. 164; A.J. Qaisar, *op. cit.*, plate 18b (see appendix 'C'). The original is in the Science Museum, London, No. 1936-235.
The barrel of a gun shown in parts in the *A in-i Akbari* (Sir Sayyid Edition) is again misleading. No such drawing appears in the original MSS of the *Ain*. Alvi and Rahman have described it thus "(The cannon was) 'made up of five parts screwed one into the other' (*op. cit.*, p. 10, plate 4).

45. Irfan Habib, "Technology and barriers, *etc.*", *op. cit.*, p.158 ("There is little doubt that the efficiency of the wooden implements was greatly effected by the minimal use, or even virtual absence of iron").

Technological Aspects of Some Fire-Arms in Mughal India

PANKAJ KUMAR DUTTA

Historical accounts of the Mughal period often mention a fire-arm called 'Ban'. It was a kind of flying-fire with automatic take-off capability. Nineteenth century European scholars and chroniclers had accepted the work 'rocket' as English equivalent of 'Ban'.

In *Ain-i-Akbari* we came across a list of weapons used by the Mughal army. In that list 'Ban' comes as item No. 77[1]. Akbarnama had also made some casual remarks on rockets as follows:

"Kahak Banha (rockets) which are kind of fire-works were being dishcarged against the imperial army ..... and that one of them fell among thorn bushes and made such a noise that one of the enemy's most notable elephants got alarmed and by confusion produced a great rout among the foe."[2]

Large number of references about rockets can be found in the historical literature of the period of the grand Mughals as well as those of the later Mughals. Quoting Ashob' Irvine reported that when Nadir Shah captured

Delhi he had siezed huge number of rockets from the artillery-men of the Mughal army.[3]

Ban or Rocket was an important military equipment of the Indian Army from 16th to 18th centuries and even upto the first half of the 19th century. But in the 18th century, its fame reached its zenith due to the military geniuses of Haidar Ali and Tipu Sultan. In 1783-84, Tipu sent an envoy to the court of the Ottoman Sultan at Constantinople. Some rockets and other valuables were offered as presents. Mir Hussain informs us that "the presents sent to (Constantinople) were all approved and accepted, but that among the war-like weapons none were so much esteemed and admired by the Sultan of Room (Constantinople) as the rockets of which there was 'none in that country."[4]

Tipu knew very well the military value of the rockets and considerably increased the number of rocketmen. He also renamed the rokets as "Shihab" meaning falling star.

In the collection of the Victoria Memorial there is water colour painting of Tipu's rocketman. It was painted by James Hunter (Victoria Memorial Catalogue No. 1340) in the later half of the 18th century. Holding the rocket in one hand the rocketman was about to release the rocket. He was not taking help of any tackle in discharging the rocket.

There is no information of any surviving rocket specimen of Akbar-Jahangir period. The two rockets preserved in the collection of the Victoria Memorial were presented by the Nizam of Hyderabad in 1905. In the information sheet, the rockets had been called 'Ban' or

'Nadi'. These were reported to be a part of the stock made in Golconda at the time of Aurangzeb's invasion of the fort during the reign of Tana Shah. Mysorean rockets as well as some later varieties can be found in the Pattern room of Fort William, Calcutta and in the Museum of Artillery at Woolwich (U.K.).

In addition to the pictorial presentations, we had at our disposal descriptions of rocket in several works of European authors like Forbes, Moor, Wilks and Fitzclarence. Most of them were in India during the mid-18th or early 19th century and naturally, their descriptions were related to the objects of that period.

According to these descriptions, a bigger rocket consisted of an iron tube 15 to 25 cms in length and 5 to 8 cms in diameter. Generally speaking it was tied with leather straps to a bamboo stick whose length varies between 1.5 to 2 metres. Bigger tube and longer stick had been reported by some authors.

In case of bigger rockets the iron-tube or container held nearly 500 gms of gunpowder which enable the rockets to fly a distance of nearly a kilometre. During the flight most of the rockets used to make appreciable noise.

There are several varieties of rockets *viz*. 'Kashak Ban' 'ground rocket'-exploding type as well as dagger and spike fitted varieties. The 'Kashak Ban' is a special type of rocket that made some loud noise. The sound was generated probably by some additional whistle like contraption attached to the tube or to the shaft. The 'ground rockets' "have a serpentine motion and on striking rise again and bounce along till their force be spent".[5] In the exploding

type the gunpowder at its extremity causes it to explode when it has reached its object. In dagger or spike fitted varieties the dagger-blade or the spike was fitted to the fore-end of the shaft or the stick.

Generally speaking, the rockets were not thrown like a javelin but just released. Hunter's painting preserved in the Victoria Memorial supports the above statement. However a few authors had reported that sometimes an additional impetus was given to them by the rocketmen. Williamson mentioned the fact in the following way: "The Fuse at the vent is lighted, the direction is given by the operator. A slight cast of the hand commences the motion and then the dangerous missile proceeds to destination.[6] In fact, the rocketmen were all trained to give the rockets an elevation proportional to the varying dimensions of the cylinder and the distance of the object to be struck as those projected to any distance to describe a parabola of considerable height, a single rocket is easily avoided but when the flight is numerous, the attempt would be useless and their momentum is always sufficient to destroy a man or horse."[7]

In several Mughal manuscripts Irvine had noticed the word 'Qaichi-i-Ban'.[8] He suggested it to be a stand used for launching rockets. A number of Mughal miniatures of Jahangir-Shahjahan period had depicted stands attached to guns. Red Fort Archaeological Museum has a mounted 'Shutarnal.' It is a small cannon that can be carried on camel. Its mount reminds us of the scissors. Irvine's suggestion about 'Qaichi-i-ban' may be accepted. The 'X' shaped tackle with the shaft of the rocket itself makes a comfortable stand for launching rockets. Tackles of this

nature are still used by washermen for tightly stretching ropes to hang wet clothes for drying under the sky. The simple design of the 'Qaichi-i-Ban' provided enough scope of quick and easy adjustment of the elevation of the rocket resting on it. In the early years the 'Qaichi-i-Ban' was a helpful tackle of the 'Bandar'. However we will not be wrong to say that in the later period 'Qaichi-i-Ban' fell into disuse. During the later period after igniting the fuse the rockets were released by hand without any help from the above tackle. Perhaps it is for this reason the new work 'Ban-ondaz' was introduced.

The question now is about the position taken by the rocketmen in the field of battle. In his account of the Battle of Samugarh (in 1652) Bernier had left some remarks on this point. He had mentioned that Dara placed in front all his cannons in a line tieing each other with chains, then lined a great number of camel-guns followed by the musketeers of the cavalry and the rest. "Aurangzeb and Murad also put their army almost in the same order, except that in the midst of the troops of some 'Omraw' they placed some small field pieces. They hardly made use of any more art, only they placed here and there some men casting 'banners' which is a kind of grenade (*sic* rocket) fastened to a stick, that may be cast very far through the cavalry, and which extremely terrifieth horses and even hurts and kills sometimes."[9] In eighteenth century Haidar Ali employed large number of rocketmen in the Mysore army. His usual tactics were to post his artillery in advance, his lines of 'musketeers' in rear of them, and the 'Bandars' or rocketmen on the flanks."[10]

From a reference in the Tuzuk[11] it may be suggested

that the Rocket Corps was a part of the Artillery. But during the later period most porobably the rocketmen existed as a separate body as they were rated separately in officail books.[12]

From the days of Jahangir to that of Haider Ali, rockets, were carried cheifly on camels[13], quoting, 'Ashob' Irvine reported that each camel carried ten rockets besides the rocketmen. At times rockets were carried on carts, each cart carrying fifteen rockets besides the necessary attendants.[14]

In *Agnapatra* (an eighteenth century Marathi treatise Ramchadranpant Amatya had given several instructions on the management of ordnances and magazine in forts. His suggestions regarding storage, care and upkeep of rocket *etc.* are quoted below:

> "(Ban), (Hoke)" *etc.* should be kept in the central room of the celler free from moisture.
>
> Every fortnight hawaldar would take out *Daru* (Gunpowder), and heat it in the Sun and again keep it in the celler duly sealed".[15]

This is all that can be collected from different accounts and memoirs on Indian hostory of the Mughal period.

The two rockets preserved in the Victoria memorial are more or less similarly constructed. The rockets have variations only in the dimensions of the powder containers and those of the shafts. The length and the diameter of the container of the bigger rocket are 25 cms and 5 cms respectively. The shaft has a length of 1.25 metres (approximately), the diameter being only 2 cms. A thin

slice measuring 26 cms was taken off from the shaft near its fore-end. This was done to house the powder container. Generally speaking the powder container is cylindrical in shape. Its one end is closed (henceforth this end will be called the vent-end). While the other end remained open till the pouring in of the gunpowder (this end is to be called muzzle-end). After loading, this later end had been sealed with a circular iron plate placed over the charge and then the side wall was made to collapse over the circular plate. There is an orifice in the central region of the vent-end for the purpose of ignition. The shaft holds the container with the muzzle side near the front-end of the shaft. Some variations are noticed in the design of the container of the bigger rocket. The container is constricted in the middle along its longitudinal length. Sharp edges had been avoided in its design, as far as possible, specially on the vent-end. The diameter of the container on the vent-end is slightly less than the diameter on the muzzle-end. These variations were done probably for improving the grip between the container and the shaft as well as for improving the flight capability.

The iron-containers were made by usual hammering method and not by forgewelding technique. The containers are still loaded with gunpowder.

These two rockets are unique in many respects and further investigations should be carried out, by competent scholars, specially on the following points:

1) The date of the rockets should be confirmed by experts.

2) The gun-powder should be analysed for determining

in proportions of the different constituents used in its making. The rocket is needed for finding out the difference between gun-powder used in the rocket and that used in cannons and guns.

3) Vigorous search should be made to find out other existing rockets. The Arsenals and Military Museums in U.K. should also be contacted for this purpose.

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9

Development of Technical Education in Colonial India

AMITA DAS

Modern technological education, mainly engineering, was introduced for the first time in India by the British in the mid-19th century, and that too, on a limited scale. As far as the various indigenous crafts and technologies were concerned, the traditional method of technical training continued to be a system of apprenticeship in domestic manufacturing units. We know that Indian manufactures could compete favourably with the products of other industrially advanced countries of the world in the 17th and early 18th centuries mainly because of their high quality. Subsequently, the introduction of machinery as a result of the Industrial Revolution required a different type of technical skill which the Indian artisans lacked. In fact, India's technological backwardness began with the close of the 18th century and increased proportionately with the triumphant progress of British mercantile and industrial capitalism. Indian industries met with a great set-back between 1757 and 1813 and the technological gap between India and the European countries widened. In these circumstances, the country needed the aid of

western scientific knowledge and technical know-how for its own agricultural and industrial development.

THE NINETEENTH CENTURY SCENE

To begin with, the East India Company's Government in India was not committed to promoting western technology or technical know-how in the country. It is well-known that the Western system of education introduced by the British in India was highly literary and designed primarily to produce clerks for the British administrative machinery and commercial houses. However, as the Company's Government began to undertake the construction of roads, bridges, canals and new townships, the need for trained personnel to fill the lower ranks of the Government's engineering projects and the Public Works Department gave rise to a few engineering and survey schools. There were also technical schools attached to the Ordinance factories at Madras, Calcutta and Bombay to train mechanics for those factories. Schools for the training of overseers came up in 1854. In Bombay, an engineering institution existed as early as 1824. An engineering class to train Indians in survey work and civil engineering was opened in the Elphinstone Institution in 1844. It was unfortunately closed down after three years due to lack of students. In July 1854, the Poona Engineering Class and Mechanical School was opened to train personnel for the Public Works Department.

The first engineering college in India owed its origin to the Government's construction work on the Ganges Canal set up in Roorkee in 1847. On the recommendation of Mr. Thomason, Lt. Governor of the North West

Provinces, it was decided to establish a permanent College for Civil Engineering at Roorkee in 1849. The main building of the College for Civil Engineering at Roorkee was completed in 1856 and it was named the Thomason College of Engineering after its preceptor. The College is now known as the Roorkee University and has the distinction of being the first technical university in the country. Engineering colleges were set up in the three Presidences soon after. In 1863, Sir Cowasjee Jehangir Readymoney donated Rs. 50,000 to the government, which helped in establishing an engineering college affiliated to the Bombay University in 1866. In Madras, a Civil Engineering College was established at Guindy in 1858 to train candidates for the grades of sub-overseers and assistant engineers only. It was much later that this Engineering College offered degree courses in civil, mechanical and electrical engineering. In Bengal, although the Council of Education had sanctioned a Chair of Engineering to the Hindu College at Calcutta in 1844-45, the scheme had not materialised. On the basis of Dalhousie's recommendations, the Bengal College of Civil Engineering was started in November 1856 at the Writer's Buildings at Calcutta. The college trained men for the Public Works and Survey Departments of the Government and also for the companies engaged in railway construction. It was affiliated to the Calcutta University in 1857 and became a department of the Presidency College in 1865. Finally, on 5 April 1880, the Engineering Department was transferred to Sibpur, near Calcutta, and was named the Government Engineering College, Howrah.

Private individuals, both British and Indian, sometimes took the initiative in establishing craft and industrial

schools. In 1840, Major Maitland opened an Industrial School in Madras for the training of ordinance artificers. In 1843, Dr. Buist founded an industrial school at Sewri in Bombay which was intended "both for the reformation of juvenile criminals and for the improvement of industrial arts". With a donation of Rs. 30,000 from the Sassoon family, this institution came to be known as the David Sassoon Industrial and Reformatory Institution in 1857. Two industrial schools were opened by Dr. A. Hunter at Madras in 1850 and 1851 for imparting training in handicrafts. These schools were amalgamated and taken over by the Government in 1855. Raja Rajendralal Mitra established the Industrial Art Society at Calcutta in 1854. In May 1853, Sir Jamsetjee Jeejeebhoy donated Rs. 100,000 to set up a School of Arts and Manufactures in Bombay and so the J. J. School of Arts came up in Bombay in 1856. Thus, private initiative was active in the field of industrial training even before 1857.

In the 1870's, on one hand Mahendralal Sircar, Rajendralal Mitra, Nawab Abdul Latif Khan, and Father Lafont of St. Xavier's College tried to create an interest in science among the public by lectures, talks and demonstrations, on the other hand, a considerable number of educated Indians felt that public and private efforts should be directed primarily towards providing and improving the facilities for technical education. A controversy developed regarding pure scientific education versus applied technical education. It had very strong protagonists on either side. A large number of people believed that technical education was the primary need of the country and the only means of economic betterment of the people because agricultural improvement and

industrial growth depended on it. Many leading Indians took the initiative in starting schools and societies for technical education. Keshbchandra Sen founded a technical school in November 1870. Nawab Syed Khan, a landlord in Patna district in Bihar gave a generous donation in 1875 for the promotion of technical education which led to the founding of the Bihar College of Engineering in 1896. Numerous vernacular newspapers and journals championed the cause of technical education. Rev. Krishnamohan Benarji, one of the early Derozians and President of the India League (1857), was in favour of the promotion of technical education. Sisir Kumar Ghosh, the founder-editor of the *Amrita Bazar Patrika*, was also of the opinion that technical education was the primary need of the hour. With a view to promote technical education, he and his compatriots founded the 'Albert Temple of Science' in April 1877 shortly after Mahendralal Sircar founded the 'Indian Association for the Cultivation of Science' in July 1876 for the pursuit of basic scientific research. It was thought by many that these two organisations should unite and combine their resources for the pursuit of science, basic and applied. But the protagonists of the two schools of thought could not come to an agreement. The perserverance and untiring efforts of Mahendralal Sircar and Father Lafont gradually succeeded in enlisting popular support for science education. Their lectures on scientific subjects drew the intellectuals to Calcutta. The Indian Association for the Cultivation of Science continued to flourish and became the home of Indian scientists in late 19th century India. On the other hand, due to lack of funds and popular support, Albert Temple of Science declined and its programme for

technical education was never implemented (Biswas, A.K., 1969).

At the close of the Company's Rule in India, therefore, technical education was dispensed by four engineering colleges, a few survey schools, and by industrial, art and crafts schools. The three universities at Calcutta, Madras and Bombay were established by the Government of India Act of 1857. The Bombay University did not hold its first Entrance Examination until 1859. In 1857, 162 candidates passed the Entrance Examination of Calcutta University and 54 students passed the Matriculation Examination of the Madras University (Majumdar, B. B. and Majumdar, B. P., 1967). The number of successful candidates who passed out of the three universities in various examinations during a period of ten years from 1864 to 1873 was as follows and the figures also give an idea of the limited appeal technical education had in India at the time.

	Calcutta	Madras	Bombay
Matriculation	8025	3974	1970
First Arts	2055	1127	321
B.A.	860	296	168
Hons. and M.A.	216	9	34
Law	704	78	33
Medicine	496	10	94
Civil Engineering	36	8	83
Total	12392	5502	2703

Source: Majumdar R, B.B. and Majumdar, B.P., (1967), *Congress and Congressmen in Pre-Gandhian Era*, 1885-1917, Calcutta, p.183.

The figures clearly show that the number of graduates in civil engineering was negligible compared to those who

graduated in the arts subjects. Civil Engineering was the least popular of the three professions. Among the professional courses Law attracted the largest number of students, followed by medicine. In 1885-86, 175 students passed the Law examinations from the three Universities; 104 students qualified in medicine while only 23 students graduated from the engineering colleges. In the whole of India in 1885-86, there were 16 colleges for law, 4 for medicine and 4 for engineering. The law classes attracted a sufficient number of students to be financially self-sufficient, while the Government had to incur considerable expense on education in medicine and engineering. During the five years from 1886 to 1892, there was no marked increase in the number of pupils in the engineering colleges. The engineering and surveying schools, on the other hand, proliferated and gave technical training to over a thousand pupils (Mahmood, S., 1895).

The Famine Commission of 1877-78 first drew the attention of the Government of India to the need of developing industries in the country to provide alternative employment to the people depending on agriculture and the consequent necessity to promote technical and industrial education in the country. The British Government, however, did not take any immediate steps to improve or expand the existing facilities in this direction. Technical education was provided by the Normal, Art and Technical Schools numbering 155 with a total of 6864 students in 1877-78 (Hunter, W. W., 1882). Teachers were also trained in these institutions. The Government Art Schools at Madras, Calcutta and Bombay in fact began as industrial schools for the training of workmen and artisans for public employment.

The indifference of the British Government to the need to provide facilities for technical education to Indians was evident from the fact that when Lord Ripon appointed an Education Commission in 1882, the subject of technical education was not included in its agenda.

NATIONALIST DEMAND

The demand for technical education was one of the persistant outcries of the Indian National Congress. As early as 1887, the Congress passed a Resolution that the Government should elaborate a system of technical education suitable to the condition of the country ..... (Zaidi, A. M. and Zaidi, S., 1976). A Resolution on technical education became a regular feature of the Annual Session of the Congress. In 1888, the Congress urged the Government to set up a Commission to enquire into the "present industrial condition of the country" as a preliminary step to the introduction of technical education on a wide scale. K. T. Telang, Pherozeshah Mehta and others urged the Governor of Bombay, Lord Reay, to establish "a technical institute of a highly scientific character for the Presidency" (Telang, K. T., 1912). It was the first Jubilee Year of Queen Victoria's reign, and the new technical institute, founded by donations from Sir D.M. Petit, the Bombay Corporation and the Ripon Memorial Fund collected by Telang, Pherozeshah Mehta and others came up in the industrial district of Byculla in Bombay in 1887. The Bombay Government provided an annual grant of Rs. 25,000. It was named the Victoria Jubilee Technical Institute (VJTI). The VJTI provided courses in mechanical and electrical engineering, textile manufacture, technical

and applied chemistry, sanitary engineering and plumbing, enamelling, sheet-metal working, mechanical drawing and training of motor mechanics.

In 1891, while moving Resolution III on Education at the Annual Session of the Congress, Heramba Chandra Maitra pleaded for the provision of educational facilities which would open many more employment opportunities than the posts of clerks and subordinate officers in Government service. In 1892, Brojendranath Seal moved the Congress Resolution on Education and pointed out the short-comings of the Government's education policy. Speaking on technical education he remarked: "We do not hear a word, however, of the polytechnics or technological institutes or even of the agricultural, commercial or industrial schools of the secondary grade, which among the continental nations have borne such splendid fruit in equipping them for the struggle for existence all over the globe, and which England is now fast developing for the sake of her own most cherished and vital interests".[7] He pointed out that while other Asian countries like China and Japan were devoting all their energies to develop science and technology, and progressive Indian States like Mysore and Baroda had taken great strides in developing facilities for modern education and training, the British Government in India presented a "unique spectacle of a civilised Government with the noblest traditions practically renouncing some of the gravest responsibilities and functions of all civilised Governments, and reversing its own just and enlightened policy of a hundred years".

The cooperation and active encouragement by the

Government was considered essential to promote scientific and technological education not only because government funds were needed to set-up institutions for technical education, but government patronage was necessary to provide employment opportunities to the technically trained young men. The Congress urged the Government to throw open the higher offices in the Public Works Departments, Railways, Forest and Post and Telegraph Departments to Indians. In 1894, the Congress advocated "the expediency of establishing technical schools and colleges," and repeated this demand practically every year thereafter. The Government met with a lot of criticism from the Indian Press because of its lukewarm attitude. In 1898, the Congress recorded its firm conviction that "the system of technical education now in vogue is inadequate and unsatisfactory". The same opinion was repeated in 1899 (Resl. XVI), 1900 (Resl. VIII), and 1901 (Resl. XIX). The nationalist leaders strongly objected to the indifferent attitude of the British Government to this very important issue. In fact it was not until after the First World War, when the British Government actually faced the consequences of India's industrial backwardness that some thought was given to reorganising education in India to give it a somewhat technical and vocational bias at least at the secondary stage.

One of the popular myths that the British propagated was that Indians were averse to practical sciences and all activities involving physical labour. F. W. Thomas writing on Indian education in 1891 commented: "Meanwhile technical education is still under consideration. The medical profession is not popular, and civil engineering is shunned by the educated Hindu, who scorns anything

practical or involving bodily labour" (Thomas, F. W., 1891). He overlooked the fact that Indian opinion was growing strongly in favour of technical and industrial education for the economic development of the country. As Thomas himself said, "It is not high education that India needs, it is practical scientific education ..... It is to the spread of practical knowledge, the influence of which can be impaired by no sophistries, religious or otherwise, that we have chiefly to look not only for the advance of material propriety which is so greatly needed, but also for the breaking down of prejudice and the encouragement of fellow-feeling between men. Under these circumstances, too much stress cannot be laid on the desireability of technical education now so long promised, and of a great extension in high schools and colleges of the study of the physical sciences" (Thomas, F. W., 1891). Scientific and technical education was not only of immediate value but was also indispensable for laying the foundations of future economic progress of the country.

AT THE TURN OF THE CENTURY

At the close of the 19th century in India, besides the 4 engineering colleges and 24 engineering and surveying schools, there were a number of industrial schools imparting rudimentary training in carpentry, smithery, shoemaking, tailoring, metal-work, weaving, masonry, cane-work, and other handicrafts. In 1902, there were 123 such industrial schools in the country with about 5000 pupils. Of these, a few important ones were managed by the Government, some by municipalities and local boards, and the majority by private bodies, mainly missionary, under a system of

grants-in-aid. These industrial schools were, of course, more in the nature of craft schools than technical institutions. It was often the case that persons trained in the industrial schools sought clerical and other jobs instead of taking up the trade they were taught. In some cases., the training given in the industrial schools was not of a sufficiently high standard, and in most schools training was mainly given in carpentry and blacksmiths' work.

The four Government Schools of Art at Calcutta, Madras, Bombay and Lahore promoted not only Fine Arts, but also Industrial Arts, and as such were under the control of the Director of Industries. There was provision for some measure of vocational training in these Art Schools such as designing, drawing, painting, modelling, photography and engraving which could be utilised by the graduates to earn a living.

As yet there was no university course for specialised training in business. Commerce could be studied as an optional subject in secondary schools only. Provision for agricultural education was also inadequate. There were agricultural colleges in Poona and at Saidapet in Madras offering 3-year courses and agricultural schools at Kanpur and Nagpur with 2-year courses. The school at Kanpur gave training to subordinate revenue officials, while the one at Nagpur had special vernacular classes for sons of landowners and others. In Bengal, the engineering college at Shibpur offered a two years' agricultural course to students who had already passed the B.A. examination of the University. Surprisingly enough, there was no provision for agricultural education in the land of the Five Rivers, the Punjab. The main drawback of the system was that in

all the agricultural colleges and institutions, the medium of instruction was English. This prevented the majority of agriculturists from taking advantage of the system. On the whole, there was not a single institution in India under the British which offered complete and practical agricultural education. The existing agricultural schools and colleges neither produced research scientists nor trained many practical agriculturists. They mainly produced men for government service.

TECHNICAL SCHOLARSHIPS SCHEME

With the rising nationalist pressure demanding economic and industrial development of the country, the British Government had to take a fresh look into the state of technical education in the country. In 1904, Lord Curzon convened an Educational Conference at Simla to review the state of the entire education system in India. but only European educationists were invited to attend this Conference. Lord Curzon admitted that technical education in India had been mainly directed to the type of instruction required to train men for Government service. He was referring to the four engineering colleges at Roorkee, Shibpur, Poona and Guindy, the VJTI in Bombay and the engineering school at Jabalpur. These had not helped in the process of developing indigenous industries in which Indian capital could be invested. The Government admitted that the provision of technical education for the economic development of the country was imperative. But instead of providing wider facilities for technical education within the country it decided to take the easy way out, i.e., provide scholaraships for

technical education abroad. The Government Resolution on Educational Policy of 11 March 1904 stated: "As a step towards providing men qualified to take a leading part in the improvement of Indian industries, the Government of Indian have determined to give assistance in the form of scholarships to selected students to enable them to pursue a course of technical education under supervision in Europe or America." The examples of Siam and Japan were quoted. The British Government also reiterated its patronage of industrial schools which would dispense "technical education of a simple and practical type, industrial training of local importance and of a high standard, commerical instruction with practical training and adapted to Indian needs, provision of more suitable types of agricultural courses and the promotion of Indian arts and industries through Indian schools of arts." In other words, it was maintenance of status quo with the exception of introducing the Technical Scholarship Scheme. This scheme, however, proved to be less than satisfactory. Initially only 10 such scholarships were given annually. Of the 113 students who went abroad between 1905-1917, it was found in 1917 that 36 were still doing their course, 5 were employed in industrial firms abroad; 4 employed in the Indian States; two scholarships were cancelled; 2 refused to return, 2 opted for higher training, 3 died, 2 were absconding. Of the remaining, the majority was employed either by the Government or by private industrial concerns in India, some left the technical line altogether, and some were unemployed. In 1917, the Government appointed a special committee, known as the Morison Committee, to suggest ways and means of improving the entire scheme.

On the recommendations of the Committee certain changes were introduced. The Provincial Governments were given the power to select the candidates and preference was given to industries such as textiles, mining, pottery, tanning, matches, glass, sugar, pencils and paper.

The British view that Indians were not keen on technical studies was questioned by the nationalists. Ten Government Scholarships a year for technical education in foreign universities was considered too few for the country. The nationalists also questioned the validity of the British Government's policy of keeping the main industries of the country under foreign ownership and management. In 1904, an "Association for the Advancement of Scientific and Industrial Education of Indians" was founded at Calcutta under the leadership of Surendranath Banerjee, A.M. Bose and K. C. Banerjee. The object of the Association was to raise a lakh of rupees annually to grant scholarships for technical studies abroad, to help the scholars set up new industries on their return, and to establish a science laboratory at Calcutta. The Association started by giving 16 scholarships in 1904. It was reported in 1916-17 that 156 of its scholarship-holders returned after completing their education and out of them 140 were employed. It is interesting to note that the majority of the scholarships granted by the Association was for technical training in the US and Japan and the subjects of study were agriculture, leather, mechanical and electrical engineering, applied chemistry, spinning, weaving, handlooms, matches, soap, buttons, enamel, sericulture, glass and mining.

THE NATIONALIST INITIATIVE

In 1904, the Congress urged that there should be at least one central polytechnic institute in the country and numerous technical schools and colleges in the Provinces. The nationalists condemned the system of education introduced by the British in which the emphasis was more on literary rather than scientific and technical education. The leaders asserted that due attention must now be given to technical and vocational education, and that such education must be within the reach of the average Indian. In 1904-05, the Central Government's grants for technical education amounted to Rs. $2\frac{1}{2}$ lakhs per annum recurring. From 1918-19, an additional Rs. 30 lakhs per annum recurring was devoted to agricultural education.

The nationalist demand for technical and vocational education formed an integral part of the Congress agitation for a national system of education. As a result of nationalist initiative in the field of technical education, the College of Engineering and Technology was founded at Jadavpur, a suburb of Calcutta, in 1912 by the Society for the Promotion of Education in Bengal or the Bengal National Council of Education. Another national effort was the Indian Institute of Science at Bangalore established in 1911 by a donation from Sir J. N. Tata. The Institute aimed at promoting the cultivation of both pure and applied science. It started functioning from July 1911 with Departments of General and Applied Chemistry and Electrical Technology. The Department of Physics was started in 1933. The Bose Institute at Calcutta, the Calcutta Technological Institute, the National medical College also owed their existence solely or mainly to

private effort. An engineering college was attached to the Banaras Hindu University in 1917 also as a result of the movement for national education. It provided a combined course in mechanical and electrical engineering for the B.Sc. degree in engineering. The Banaras Hindu University also had departments of mining, metallurgy and glass technology.

COMMITTEES AND COMMISSIONS

The Indian Industrial Commission of 1917 was the first official attempt to review the subject of technical education in India. The Commission was presided by Sir T. H. Holland, and included, among others, certain leading Indian industrialists, viz. Sir R. N. Mookherjee, Sir D. H. Tata and the eminent Indian educationist Pandit Madan Mohan Malviya. The Holland Commission, as this Commission was popularly known, strongly recommended that the existing engineering colleges and universities should be expanded to meet "the increasing need in India for Scientific, Technical, and Technological training". The Commission was mainly concerned with making provision for higher technological training in India so that the physical science students of the Colleges affiliated to the Universities would have the opportunity to avail themselves of such training. The War of 1914 had given ample warning to the British that unless certain essential industries were developed in India, the Empire would face dire economic problems during times of war and other external crises. The four engineering colleges had so far been concentrating on civil engineering and meeting the requirements of the Public Works Department by training

Indians to qualify for the posts of subordinate officers, surveyors and draftsmen.

The experience of the First World War brought about a change in the attitude of both the Government and the leading foreign investors in India. They realised the importance of promoting certain basic manufactures in India which were necessary for industrial self-sufficiency and for strategic and defence purposes. For instance, the war gave a spurt to the Indian steel industry. Many British firms now thought of establishing branches of their own specialised industries in India. The war also gave an opportunity to Indian entrepreneurs to start engineering and metal-manufacturing industries. Attention of the foreign industrial employers in India was also drawn to the fact that it was unwise to depend entirely on imported personnel for supervision of engineering industries and that Indians ought not only be given opportunities for higher technical training on a much wider scale than in the past but also an opportunity to apply their knowledge to industry.

The Holland Commission suggested that the simplest way of achieving this would be to expand the existing engineering colleges into technological institutes by creating new departments and by shifting the emphasis from civil engineering to mechanical and electrical engineering. The Commission further suggested: "It would be advisable to proceed further and establish imperial colleges of the very highest grade. Two at least would be needed, staffed with specialists of high reputation who must be provided with adequate equipment for both teaching and research work". The Commission further

suggested that of the two higher technological colleges, one should cover all branches of engineering, while the other should be concerned with metallurgy and mineral technology. It was obvious that in post-war India, metals and minerals had to be given priority if the country was to achieve some measure of industrial self-sufficiency. The Commission also recommended that an Institution of Civil Engineers on the British pattern be established. In fact, the Institution of Engineers was founded in India in 1920 and became a professional society with the largest membership in the country.

The Calcutta University Commission or the Sadler Commission (1917-19) which was contemporaneous with the Indian Industrial Commission (1916-18), however, shifted the emphasis from higher technological education to technical education of a more general type. The Government Resolution on Educational Policy, dated 21 February 1913 had stressed the need for the creation of new universities of the teaching and residential type as "the right road to educational efficiency." The First World War, however, prevented the implementation of any of the policies spelt out by the Government Resolution of 1913. In 1917, the Calcutta University Commission was appointed under the Chairmanship of Dr. M. E. Sadler, Vice-Chancellor of Leeds University, to study and report on the educational needs of the country. The Commission not only investigated the problems of the Calcutta University but also reviewed the working of other Universities in India. The report of the Commission, therefore, was of all-India importance.

The Sadler Commission asserted that "It is an important

and, indeed, a necessary function of a University to include science and technology in its courses and to recognise their systematic and practical study by degrees and diplomas". The Commission deplored the over-crowding of purely literary courses of study in the Universities and yet was conservative in its approach to the question of technical education. It pleaded that unless qualified teachers, up-to-date equipment and adequate number of jobs could be provided, the provision of technical education would create more problems than it was expected to solve. Moreover, the Commission was firmly of the opinion that degree-courses in technical and professional subjects other than medicine and law were relevant only in industrially advanced countries. As India was just on the threshold of industrial development, the Commission felt that there was need for "a very large number of men who are intelligent and educated, and whose training has given them some introduction to the sciences at the base of their calling, but who cannot be called scientific experts". The Commission, therefore, was of the opinion that there should be Intermediate Colleges offering varied courses with vocational bias although the education offered would still be general in character. There was no concrete guide-lines on the matter of technical education in the Sadler Commission Report besides such general observations.

The Sadler Commission clearly sabotaged the recommendations of the Holland Commission so far as technical education was concerned. Consequently even as late as the 1920s there were no departments of applied science and technology, other than engineering, in any of the Universities in India. As a result, a large number of

Indian students went abroad to U.K., Germany, America, Japan and elsewhere, for training in technology and applied science. There were about 1500 Indian students in England in 1921. Majority of them studied civil and mechanical engineering in the English universities. The total number of Indian students of technical sciences in England was 321 in 1926-27, 318 in 1931-32 and 220 in 1936-37 (Nurullah, S. and Naik, J.P., 1951).

It was obvious that the 4 Engineering Colleges in India could not accommodate the increasing number of students who desired higher technical education. Besides, the courses in these colleges still followed the pattern set in the 19th century. They were regarded as "mere appendages of the Public Works Department." The training courses in agriculture and forestry were also under the control of the Government Departments concerned and were geared to meet the department needs only. The Government's attitude was amply clear considering that the Government of India sent its forestry probationers to England instead of making fuller use of its own Institute at Dehra Dun. Technological training was, however, not freely offered by the English firms to trainees from India and other countries. British industries, such as textiles, chemicals, leather, glassmaking, were unwilling to fully impart their technologies and trade secrets to Indian students or give them sufficient training in their factories. The usefulness of advanced tehnological training abroad was also doubtful as Indian industries and factories were not as well-equipped with modern machinery as those in the industrially-advanced countries. Under such circumstances, public opinion in India was strongly in favour of establishment of technical schools and higher

technical institutions in the country. It was argued very pertinently that India could not depend forever on other countries for technical training and education. The Committee on Indian Students in England (1921-22) or the Lytton Committee, also strongly criticised the practice of sending Indian students to study, law, medicine, administration and technology in Britain and recommended that institutions for higher studies and training in all these fields should be developed in India itself and that "would be a natural instead of an unnatural system."

Despite the growing awareness that India needed more facilities for technical education both at middle and higher levels, there was no definite plan to organise such education in India as late as 1930s. Between 1921-36, the number of university graduates rose by leaps and bounds and added to the problem of the educated unemployed. In 1921-22, there were only 44 professional colleges in India of which 13 were for law, 12 for education, 7 for medicine, 5 for engineering, 5 for commerce, and 2 for agriculture. Law attracted the maximum number of students, followed by medicine, engineering, education, commerce and agriculture. Law, medicine and education attracted over 10,000 students during 1920-21, whereas engineering, commerce and agriculture drew only 1608 students (Nurullah, S. and Naik, J. P., 1951). So it may be safely concluded that from 1857, when the Universities were founded, to 1921, when the Department of Education was transferred to Indian control, the higher educational system was hardly geared to the industrial and technological development of the country.

Whatever attempts had so far been made to provide vocational and industrial training had little in common with the main educational system. The industrial schools were under the control of the Director of Industries, and not the Department of Education. In order to relieve the pressure on the Universities and also to combat increasing unemployment among matriculates and university graduates it was often stressed by nationalists and experts that technical and vocational training must be introduced at the secondary stage of education. But the British Government continued to adopt a conservative attitude. The Hartog Committee Report of 1928-29 stated, "Commerce in India does not at present demand the services of any large number of highly trained men and the industries of India, apart from agriculture, are still comparatively undeveloped. . . . . The extension of technical training, which is more expensive than literary training, has been widely advocated. We fully sympathise with the desire to develop such technical training though we feel bound to point out that the training of technical experts only creates more unemployed, unless there are industries to absorb them".

THE ABBOTT AND WOOD REPORT

During the thirties the growing unemployment among university degree-holders and the lack of technical personnel to meet the demands of industry, once again forced the British Government to take up the matter of organising technical and vocational education in India seriously. In 1936, the Central Advisory Board of Education invited two educational experts from England to review

the situation and make suitable recommendations for the organisation of technical education but only at the school level. According to their terms of reference, Messrs. Abbott and Wood were requested to state whether any vocational or practical training should be imparted at primary, secondary and higher secondary levels and, if so, to recommend the nature and extent of such education. They were also to advise on the type of institutions required and the stage at which diversion of students from ordinary secondary schools to such institutions should take place.

Messrs. A. Abbott and S. H. Wood came to India during 1936-37 and based their report on vocational education on the data obtained as a result of their survey of the educational facilities then available in the Punjab, U.P. and Delhi. The report was, therefore, limited in scope. Nevertheless, the Abbott-Wood Report contained certain significant findings and recommendations. First, the importance of a good general education as the basis of vocational or technical education was emphasised. The Report also advised a planned approach in expanding facilities of vocational and technical education so that the supply of trained personnel should not create more unemployment. Instead of preferring a uniform pattern of vocational education for the entire country the Report advised that each Province should carry out its own survey regarding the educational and technical man-power needs of its industries and commerce and then determine the type of vocational education to be provided. While stressing that general and vocational education should be regarded as "the earlier and later phases of continuous

process," the Abbott-Wood Report recommended that there should be separate schools for vocational education, which should maintain close liason with industry and commerce as they were intended to meet the needs of industry.

The main drawback of the Abbott-Wood Report was that it was extremely shortsighted. It did not foresee the urgent and necessary industrial development in India in the post-World War period. In fact, it recommended an undue degree of caution in the plans for training men for organised industry, and urged that priority should be given to schemes for improving the technical skill of cultivators and small-scale industrial workers. In the organised industrial sector, the training of the supervisory grade, i.e. foreman, chargehands, and middle-rank workers, was considered more important than higher technological training (Abbott, A. and Wood, S. H. 1937).

As a result of the Abbott-Wood Report some action was taken by the Government. A few experimental technical schools were started in Bombay and Hyderabad. Many ideas on technical education at Junior and Senior levels contained in the Report were later incorporated by the M. N. Saha sub-committee on Technical Education set up by the National Planning Committee in 1938. The Delhi Polytechnic College which came up in 1941 with W. W. Wood as Principal was not very different from the combined Vocational Training College, Junior Technical School, part-time Technical School and a School of Arts and Crafts all under one management as recommended by the Abbott-Wood Report.

POST-WAR DEVELOPMENTS

Technical education once again became a matter of serious concern at the end of the Second World War. The war had given an impetus to the development of certain industries in India to meet the war demands. Technical training centres and factories came up in various parts of the country. Several post-war development schemes undertaken by the Central and Provincial Governments increased the employment opportunities of technical personnel. The matter of technical education was no longer left under Provincial control alone. The Government of India paid much greater attention to it during 1944-1947 than at any time in the past and decided to take up the matter of organisation of technical education on an all-India basis. In fact a distinctive feature of the post-Second World War period in India was that it saw the preparation of several plans for educational reform in the country. No other period in the history of Indian education received as much attention both from the British Government and from the nationalist leaders. The post-war educational plans were drawn up by both official and non-official bodies. The plan for Post-war Educational Development in India prepared by the Central Advisory Board of Education in 1944 presented the official view, while the plan of Educational Reconstruction prepared by the National Planning Committee in 1945 and published in 1948 reflected the nationalist opinion.

One of the schemes considered by the Congress was Gandhiji's "Wardha scheme" of education which envisaged a craft-centred vocational education from the primary stage. The principle of intellectual training and self-

sufficiency through a craft was the main feature of the scheme. The Congress was committed to the achievement of universal, free, and compulsory primary education but the lack of sufficient funds was the main hurdle in the way. Hence Gandhiji thought that the process of schooling could be made self-supporting by enabling the children to earn while they learn. The self-supporting aspect of the Wardha Scheme became the centre of a heated controversy. The First Conference of National Education was convened at Wardha in October 1937 to consider Gandhiji's scheme. The Conference appointed a Committee under the Presidentship of Dr. Zakir Hussain to prepare a detailed syllabus for basic education. The Zakir Hussain Committee submitted a detailed report in December 1937 containing syllabii for a number of crafts, teacher's training, examination and administration. The Haripura Congress of 1938 endorsed the scheme and it was adopted in several provinces where the Congress was in power (C.P., U.P., Bihar, Bombay) and also by the State of Kashmir. The Government of India took up the Wardha Scheme for consideration. In January 1938, the Central Advisory Board of Education appointed a Committee under B. G. Kher, Chief Minister and Minister of Education of Bombay, to examine the scheme in the light of Abbott and Wood Report and other relevant documents. During the years 1938-40, basic national education made steady progress and many schools for such education came up. The War and the consequent resignation of Congress Ministries, however, slowed down the spread of basic education.

On the Government's side, the first comprehensive plan for the reorganisation of education in India after the Second World War was the Sargent Plan of 1944. Since its

revival in 1935, the Central Advisory Board of Education had devoted its energies to evaluating various aspects of educational development in India. The Board of Scientific and Industrial Research was set up in 1940 under Dr. S. S. Bhatnagar with a view to promoting planned industrial research and development. The Board with its 15 Committees devoted itself to a wide range of industrial research. During the Second World War, such research was directed towards assisting India's war production. After the war, the Board conducted research to help the new and nascent industries founded by the government or by private enterprise, such as heavy chemicals, engineering and metallurgical industries. The Association of Principals of Technical Institutions (India) was founded on 28 July 1941 with a view to coordinate the activities of various bodies concerned with technical education in the country. The aim of the Association was to foster cooperation between educational institutions, industry and professional societies, and to prepare plans for systematic development of technical education. It was obvious that technical education would have to be geared to the needs of industry. The Association also emphasised the necessity of incorporating technical and vocational education in the sphere of secondary education.

In 1944, the Central Advisory Board of Education appointed a Committee under Dr. John Sargent, Educational Advisor to the Government of India and Joint Secretary of the Department of Education, Health and Lands, to review all aspects of education in India and formulate a post-war educational development plan. It was the first official attempt to prepare a plan for complete overhauling of the existing system of education in India

from pre-primary to the University stage including technical education.

The Sargent Plan recommended that the reorganised high schools were to be of two types: the Academic High Schools and the Technical High Schools. The Academic High Schools would impart education in the arts and pure sciences, whereas the Technical High Schools would provide training in applied sciences, industrial and commercial subjects. There would be a common core of humanities including art and music in both. In rural areas, agriculture would form a part of the curriculum. The Sargent Report specifically stated that the medium of instruction in all high schools should be the mother-tongue of the pupils, and English should be a compulsory second language. Although not totally rejecting the existing system of technical education in the country, the Report described it as "too academic in content and too far divorced from first hand contact with the needs and conditions obtaining in industry" (Pearce, F. G., 1948). The Report also stated that the existing institutions of technical education were not of a uniform standard. The Sargent Plan recommended technical and vocational education for three categories of workers, viz., (i) skilled craftsmen; (ii) minor executives, foremen, chargehands, or in other words, the supervisory grade; (iii) chief executives, and research workers. The Plan made provision for the effective training of all these types of workers.

The close link between science and technology was emphasised. The Sargent Plan stressed the fact that "Technical instruction today must be a wider and more liberal form of training than it has been in the past; it must

comprehend the scientific principles underlying the processes themselves; it must link up the science of production and business organisation with the arts of design and salesmanship" (Pearce, F. G., 1948). The Report also pointed out the urgent need in India of part-time schools for technical people already in employment. It recommended polytechnics in preference to monotechnics at the high school stage so that a wide choice of technical subjects would be available to the students. The polytechnic, schools, besides providing the technical school certificate course for its whole-time pupils, would also offer a three-year part-time certificate course for students already in employment. The senior technical institutions would cater to technicians of the supervisory grade. Higher technological training would be provided in technological departments of the Universities as well as in the Diploma courses in senior technical institutions. According to the Plan about 200,000 places should be available to students in junior technical trade and industrial schools and about 75,000 places in senior technical institutions. In other orders, the former would absorb 4 per cent of the pupils leaving senior basic schools every year, and the latter would also take up about 4 per cent of the pupils leaving High Schools. The Sargent Plan did not recommend the establishment of higher technological institutions in India. It left it to the Universities to provide higher technological training and once again placed a premium on training abroad as the following extract clearly shows : "It may be well to emphasize the necessity for ensuring that in the University technological departments ample facilities are provided for research directed towards the solution of practical industrial problems and that the need for testing

the results of laboratory experiments on a commercial scale is not overlooked. It is not less important that technological degree courses generally should be made practical than they are at present, and that students should spend a considerable part of their time throughout the course, and not merely at the end of it, in works and factories. The same applies to commercial students. A further desideratum is that as many students as possible and particularly those likely to become technical instructors, should be afforded facilities both for studying abroad and for obtaining firsthand experience of foreign industrial and business methods" (Pearce, F.G., 1948).

Indian students continued to go to the United Kingdom and the United States for higher technological training and post-graduate studies. In March 1945, the newly created Education Department of the Government of India announced the scheme for sending nearly 600 students abroad on scholarships in addition to the large number of Indian students who were financing themselves. The Government of India adopted the major recommendations of the Sargent Plan and established a separate Education Department at the Centre in 1945. The Provincial Governments were advised to draw up their five year programmes on the basis of the Sargent Plan.

By 1945, therefore, there were handful of colleges, institutes and departments of engineering and technology in India, but none of them were of international standards nor were there any institutes for higher technological training and research. Britain herself was sliding back as far as facilities for higher education and research in

technical subjects were concerned. For instance, there was no institution in Britain comparable to the Massachussetts Institute of Technology or other similar institutions of the U.S. The existing institutions at Glasgow, manchester, Birmingham and London were in need of updating and expansion. It was therefore not very surprising that as Britain's colonial dependency India lacked institutes and colleges for advanced technological training. Yet it was undeniable that India's industrial and agricultural development depended on a steady supply of technical personnel trained in research and practical training. Most experts, therefore, suggested that there should not only be facilities for basic technical training at all important industrial centres in India but that one or two technical institutes of the highest possible standard should be founded or at least developed from the existing ones, such as the Indian Institute of Science at Bangalore. These would be centres of research as well as practical training.

On the recommendation of the Central Advisory Board of Education, therefore, the Government of India created the All-India Council of Technical Education in November 1945 to advise the Central Government on the organisation and planning of higher technical education in India and on how to bring about proper co-ordination between the different institutions working in the field. Among others, the important functions of the Council were:(a) to survey the field of technical education, (b) to consider all immediate projects for the development of technical education, and (c) to prepare a scheme for co-ordinating all available resources in developing technical education on an all-India basis. The Council appointed six All-India Boards of Technical Studies one each for the

subjects of Applied Art, Architecture and Regional Planning, Engineering and Metallurgy, Chemical Engineering and Chemical Technology, Commerce and Business Administration, and Textile Technology. To begin with, the six Boards prepared Dipolma Courses on technical subjects which differed from the University Degree Courses in that they laid greater emphasis on practical training than on purely theoretical learning.

HIGHER TECHNICAL INSTITUTES—THE SARKAR COMMITTEE

In 1945, an ad hoc Committee called the Higher Technological Education Committee was set up by the Government of India under the Chairmanship of the eminent physician and educationist Dr. Nilratan Sarkar to advise the Government regarding the setting-up of higher technological institutions in India. The Committee consisted of experts representing the government, industry, scientific and technical institutes as well as the Ordnance Branch of the Army.

The Sarkar Committee, according to its terms of reference was to recommend whether there should be a central institution for higher technological education and training possibly on the lines of the Massachussetts Institute of Technology, with a number of affiliated institutions attached to it, or several higher institutions on a regional basis, or any other type of organisation. After deciding on the type of technological institution most suitable to cater to India's needs, the Committee was required to plan out the details of scope, size, site, management, teaching staff, buildings and equipment, finances and other relevant

questions related to the establishment of such an institution or institutions in the country.

The Sarkar Committee strongly affirmed that the establishment of higher technical institutions for undergraduate study at par with educational standards abroad as well as for post-graduate study and research, facilities for which were virtually non-existent in India, could no longer be delayed. The Committee also recommended that in view of the vastness of country and the location of her industries, the provision of several higher technical institutions at different parts of the country was the solution most likely to satisfy post-war requirements. The Committee recommended that "Not less than four higher technical institutions, one in the North, one in the East, one in the South and one in the West will be necessary to satisfy the post-war requirements." These institutions would provide instruction up to the graduate stage in all the main technical subjects suited to the industries in the particular region which they were designed to serve.

While reiterating the necessity of setting-up all four institutions as speedily as possible, it was decided that the one in the east near Calcutta should have priority in view of the industrial development in that region, to be followed by an institute in the west near Bombay. The Committee further recommended that to meet the demand for engineers with special training in hydraulics, the engineering nucleus of the northern institution should also be set-up without delay at Kanpur. The Committee gave a lot of thought to the nature and standard of education to be pursued in the Indian Higher Technical

Institutes (HTI). The post-war industrial and government projects required a large number of technical graduates far in excess of what the existing institutions could provide. So the main aim of the H.T.I.'s would be to provide undergraduate instruction in the main branches of technology. Moreover, as facilities for post-graduate study and research in engineering and technology were lacking in the country, the H.T.I.'s, would also train research workers and technical teachers.

The Sarkar Committee recommended that students who had passed the Intermediate Science Examination or the Higher Secondary Examination were eligible to sit for the entrance test. There was to be no quota system except that a few seats would be reserved for the backward classes. The standard of proficiency for graduates was to be similar to that of the Massachussetts Institute of Technology or the Manchester Institute of Technology. Post-graduate research would take two years or more. The proportion of under-graduate to post-graduates students was estimated at 2:1. The H.T.I. in the Eastern Zone was designed to cater to an under-graduate student body of 2000 and post-graduate departments with 1000 students. The initial outlay for land, buildings and equipment was estimated around Rs. 3 crores. While the recurring expenditure was estimated to be about Rs. 68 lakhs per year, the annual income was estimated around Rs. 13 lakhs. According to these figures, the net expenditure per student per year was estimated at about Rs. 1820. In preparing the syllabus for each H.T.I., special consideration was given to industries of the areas, actual and potential. The Sarkar Committee's recommendations were adopted by the Government of independent India. The first Indian

Institute of Technology came up at Kharagpur in West Bengal in 1950, followed by Bombay (1958), Kanpur (1959), Madras (1959) and Delhi (1961).

CONCLUDING REMARKS

From this brief retrospect one may conclude that the development of technical education in India prior to 1947 was indeed very slow. The situation was somewhat bettered from about the end of the Second World War compared to the situation in 1901-02. In 1947-48, there were 132 Colleges for professional and technical education in India: 12 for agriculture, 3 for forestry, 17 for engineering and technology, 24 for medicine, 5 for veterinary science, 38 for teachers' training, 18 for commerce and 15 for law. There were only 1,390 schools for vocational and technical education compared to 153,693 schools for general education. The 17 Engineering Colleges in British India catered to not more than 2500 students annually.

Besides the above Colleges, in the whole of India there were only 490 engineering, technical and industrial schools with a total enrollment of 27,940 pupils in 1946-47. The following chart gives an idea of our technical manpower from 1915-49.

Argicultural education, including education in animal husbandry and dairy-farming, commercial education and art education were also essential branches of technical education in India under the British. The importance of agricultural education was brought to the notice of the Government by the Agricultural Conference held in 1888. Bombay University took the lead by including agriculture

Out-turn of Degree and Diploma Holders in Engineering and Technology in India: 1915-1949

5 Years periods	Numbers Degree	Diploma	Total	Average Annual Out-turn
1. 1915-1919	568	1,703	2,271	434
2. 1920-1924	771	1,902	2,673	535
3. 1925-1929	1,619	4,322	5,941	1,188
4. 1930-1934	2,190	5,397	7,587	1,517
5. 1935-1939	2,901	5,331	8,232	1,646
6. 1940-1944	3,765	6,280	10,045	2,009
7. 1945-1949	5,965	7,404	13,369	2,674

Source: Man-Power Studies, No. 5: *Engineers in India*, (1955), Perspective Planning Division, Planning Commission, New Delhi.

as a separate subject for the degree examination. In 1901-02, there were only 3 agricultural colleges in India. By 1936-07, 6 agricultural institutions were functioning at Coimbatore, Poona, Kanpur, Naini, Lyllpur and Nagpur. By 1947, 12 new agricultural colleges were founded. The agricultural college at Lyllpur went to Pakistan at the time of partition of India. The remaining 17 government institutions for agricultural education admitted 1551 students annually. In 1947, Calcutta University decided to introduce I.Sc. and B.Sc. Courses in agriculture and in 1948 a research section was established with a Chair in Agriculture from the Khaira endowment. Even assuming that about half the number graduated each year, the number of agricultural graduates was infinitesimally small compared to the total agricultural population in the

country. The Indian Universities Commission of 1964 reported that not more than 2 or 3 per cent of the total number of agricultural graduates actually returned to the agricultural field. In 1946-47, the number of M.Sc. and doctorates from agricultural colleges was 74, while 156 candidates received post-graduate diplomas in agricultural, veterinary, forestry, dairying and allied sciences. It is thus clear that only a beginning had been made towards meeting the demand for agricultural education at the University level in pre-independent India. Agricultural research had also received some attention from the British Government prior to 1947. A policy of promoting agricultural and veterinary research had been put forward by Lord Curzon. The Imperial Institute of Animal Husbandry and Dairy-farming set up at Bangalore in 1923 and the Imperial Council of Agricultural Research established in 1929 concerned themselves with various problems of Indian agriculture. Numerous commodity research committees were also established prior to 1947. The Indian Central Cotton Committee, Bombay (1921), the Indian Lac Committee at Ranchi, the Central Sugarcane Committee at Delhi (1944), the Indian Tobacco Committee at Madras (1945), the Indian Central Coconut Committee at Ernakulam (1945) and the Central Oilseeds Committee at Hyderabad (1947) undertook research on particular crops with special attention to plant breeding, crop protection and seed technology.

Facilities for commercial education at the college level were provided by the British Government for the first time in the second decade of the twentieth century. The Sydenham College of Commerce and Economics was established in Bombay in 1914, and commerce classes

were started in the other Indian Universities soon after 1919. In 1936-37, 8 Indian Universities had faculties in Commerce. By 1947, most Indian Universities had a Department of Commerce and offered degree courses in Commerce. A few Universities like Bombay, Allahabad, Lucknow and Agra also offered a Master's Degree in Commerce. The H.L. College of Commerce at Ahmedabad was founded by private effort. The Commercial Schools were mostly run by private bodies. Out of 296 Commercial Schools in India during 1946-47 admitting 14,581 students, only 18 Commercial Schools were under Government and only 15 were aided. The Government Art Schools offered courses in industrial and commercial arts and crafts, and as such, were institutions of technical education in the country. In 1946-47 there were 14 Government Art Schools catering to only about 1700 students.

On the whole, at all levels therefore, technological education and research were kept at a low-key by the British in India. The consequences of such a policy were inevitably rising unemployment, slow industrial and agricultural development, increasing dependance on the technologically advanced countries and growing poverty.

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10

Technology in India in the Eighteenth-Nineteenth Century

AMULYA KUMAR BAG

INTRODUCTION

The technology in India in the period was highly decentralized on class basis. Some of the manufacturing castes can still be recognised from the titles like *tānti* (weaver), *karmakār* or *lohārs* (ironsmith), *kulāla* or *kumārs* (potter), *suvaṃakār* (goldsmith), *sūtradhār* (carpenter), *kāserā* (copper-smiths or braziers) etc. The enumeration of these classes which constituted various communities or castes is difficult, but there is no doubt that those classes acquired considerable proficiency and earned their livelihood through complex specialisation.[2] Stavorinus in his account of the *East Indies* between 1768-71 reports that the artificers confined themselves to one sort of work. According to him[3], "A goldsmith would not work in silver, nor a silversmith in gold. In the looms, a weaver would weave only one single sort of stuff during the whole life, unless he be compelled to take another in hand." In India the knowledge of technology was mainly traditional. Learning and training of an artisan was limited to his family.

TEXTILE

The process of manufacturing and production of textile was already a known technique in the eighteenth century. This was perhaps known traditionally from the time of Harappa and had attained a sizeable progress in the sixteenth-seventeenth century. Jean Baptist Travernier[4], in an account of 1676 reports that transparent Indian muslins were exported to Persia, Turkey, Muscovie, Poland, Arabia, Grand Cairo and many other places. The Dutch[5] also made investment to this profitable business and did not allow members of their company to engage in private trade. They exported the materials to Philippines, Borneo, Java, Sumatra and other neighbouring countries. Some of the textile crafts also reached its zenith. These crafts were either effected on the surface, or done separately or knitted side by side with the progress of the weaving. Most important of them being brocades, muslins, embroidered fabrics, tie-dyed and printed calico-cloths and the carpets.

In the eighteenth-nineteenth century also, this industry provided employment to hundred and thousands of inhabitants and countless widows, and the textile craft reached further progress. This was considered as a premier industry and captured extensive market even outside India. Hill[6] in his report on Bengal (1756-57) writes that every district in Bengal could boast of special brand and produce cloth of all kinds. Dacca in Bengal enjoyed undisputed superiority in cotton and silk cloth. Its muslin was so fine that a piece of twenty-yards in length could be enclosed in a common tobacco box (size 8" X 4" X 1").[7] The Bihar province was known for cloths of good texture, and northern India, Gujarat, Mysore, Ahmedabad and some

parts of Madras (Masulipatnam and Vizagapatnam) for durable cotton goods. The silk and woollen products in India could not be so popular as the cotton ones, but these were also produced in sufficient quantities. Calcutta and Surat were great emporiums for foreign commerce. Cotton, silk and textile stuff were brought to these places for export to European markets.

As to the technique of manufacturing textile-fabrics in the period, details are not available but from survey reports on textile preserved in the museums like Victoria Hall Museum, Udaipur, and the tribal techniques still prevalent in some parts of Bengal, Nagaland, Manipur, Madhya Pradesh, it would appear that there were various phases of operations[8]. Some of the technical operations in cotton were, *wetting* of yarn (i.e. keeping the yarn under water for 1-3 days for removing foreign substances and making it suitable for absorption of sizing materials), *sizing* (starching with flour or *til* oil for stiffness and glaze), *bleaching* (boiling in soap water or solution of impure carbonate of soda and slaked lime for making it sufficiently soft), *dyeing* (colouring with required dye), *spinning* and *winding* (transferring of yarn from the hanks to bobbins for the warp), *warping* (putting a number of threads up and down equal to the length/width of the cloth to be woven), denting (drawing warp-ends through the dents of the reed), *beaming* (winding of warp threads on warper's beam) and so on. For silk, cocoons were raised by cultivators by growing mulberry plants and rearing silkworms feeding on mulberry leaves. Cocoons were then sent to silk weavers for reeling.

After *winding*, came the art of weaving. It was usually

governed by three primary motions in a loom. The first motion was effected by the depression of the treadle by one foot thus making an opening. Then by the second motion, the shuttle was pushed by giving an oblong pull to the handle resulting a push to another shuttle of the shuttle box which ran across the opening to the other side, and by the third motion, the wept thread was beaten by drawing the sley made of bamboo or wooden rod forward. Mainly two important types of looms, viz. *throw shuttle* and *fly shuttle* were usually used. In the throw shuttle techniques, shuttle was thrown across the shed by one hand from one side and caught by the other in the opposite side of the cloth. The *fly shuttle*[9] technique was first patented by John Kaye of Bury in 1733 and perhaps introduced by the Company. In the fly shuttle technique, shuttle was pushed from one end to the other across the sley which was fitted with shuttle box by packers exerting pull by the right hand. The repeated oscillating motion was effected by hand.

Three changes in the textile technique in the period are noticeable, viz. (i) numerous filature system in reeling, (ii) drum warping, and (iii) flyshuttle technique. East India Company was interested in large scale production of textile goods and established several factories with numerous filatures for reeling. In 1769 it brought even a number of Italian reelers to teach the Italian system[10] to factory hands. In warping, the street-warping and drum-warping techniques were used. The latter was an advanced technique, for specific length could easily be obtained by marking on the drums. In the loom also, fly shuttle technique increased considerably the output of the weavers. The time and labour were very cheap in India. But this large scale production brought a great change in textile

industry. In 1815, the company established a textile mill at Broach. A few others were established at Calcutta in 1818. By 1833, Company's interest in the silk industry of Bengal declined perhaps due to silk-worm plague. Bad reeling and hard competition with Japan, China and Mediterranean countries were also considered other factors for such decline. But the cotton mills went on making considerable progress because of quicker adaptations of the large scale manufacturing techniques and superior arts and crafts. England viewed Indian textiles with alarm and indignation. Only vigorous state action in banning the use of Indian textiles strengthened English industry to stand on its own food.[11] A few cotton mills were established by the effort of the Indian themselves, one at Bombay in 1854 by Cowasji Patel and the other at Ahmedabad in 1861 by Ranchotlal. Between 1880 to 1895, a number of textile mills increased from 58 to 154, and the number of employees from 40 thousand to one and half lakhs. By the turn of the century, the textile industry made spectacular progress, and over 80 per cent of the production was still exported to China, Japan and few other places.

METALLIC AND ALLIED WORKS

From the time of Indus valley, bronze and copper were known metals in Indian tradition. According to Ray[12], *casting* (operation of pouring molten metal into moulds in which they solidify) and *forging* (shaping of hot metal by means of hammering) techniques were known to the peoples of Indus valley. According to some scholars bronze statuette of the dancing girl and a crucible with slag sticking to the edges are pointers to this direction and

conform to this suggestion. Since copper melts at 1084°C, it appears that people of Mohenjodaro could produce and control a temperature of 1084°C. The metals like silver (960°C), lead (327°C), gold (1065°C) and tin (232°C) were also known to them perhaps because of their availability and low melting point than that of copper. Iron technology (melting point of iron 1533°C) came much later perhaps because of ignorance of producing a temperature as high as 1533°C. The *cire-perdue* (lost-wax) technique was widely known in Gupta, Chola, Pallava and in the Medieval period. The *Samarāṅgana Sūtrādhārā* and *Mānasollāsa* give elaborate description of this technique. The process of extracting iron was undoubtedly crude and entailed plenty of labour, but regarding know-how, details are not available.

Campbell[13] in his survey of Madras in 1833 gave a description of a furnace being used in large numbers by the ironsmiths of South India for the production of bar iron. The furnace was of a conical shape having a height of 4 ft. 6 inches. The diameter varied from 13 inches at the bottom to 7 inches at the top. It had two openings at the bottom, for letting in the blast given with the help of bellow and the other for taking out the slag. Common magnetite iron ore (Fe_3O_4) and requisite amount of charcoal were introduced from the top. Two men were required to work on it, one at the bellows and the other to put fuel in ore, and letting out the slag. The furnace was first filled with charcoal. When it was well heated, ore was let down through a hole at the top. Some 25 to 30 basketful of ores (one basketful weighs roughly 5 to 7 seers) were consumed by a furnace in one day. The furnace was similar to the modern *blast furnace* being used for the manufacture of pig

(or cast iron). This gave bar iron of high quality containing a considerable portion of steel. The price of these bar irons was cheaper than the cheapest English bar iron then sold in India and these were in demand in England for producing steel of good quality. In Madhya Pradesh, Bihar, Bengal and Maharashtra, the medieval method of smelting iron ore and forging of iron bars are even practised now by the tribals like *Lohār, Tāmtā, Āgārias, Khuntiā, Chokhs, Mariās* and *Muriās, Birs, Asurs* etc. According to Buchanan[14], the manufacture of steel from iron ores was a common industry in Mysore district in the first decade of the 18th century. The steel wires[15] manufactured at Seringapatam for musical instrument attained very good standard and were sent to different parts of the country. Twining[16] reports that industrious inhabitants at Munger in Bihar and Birbhum in Bengal could manufacture iron utensils of almost every descriptions. They could also manufacture chairs, tables sofas, cots, bedsteads, drawers which were extremely neat and scarcely inferior to European furniture.

Attempts had been made from time to time to work on ores on a large scale by modern method by the British Government. In 1874, Bengal Iron Company was established at Barakar. In 1891 the establishement was able to employ 821 people and produced 12 thousand tons of pig iron. But by the end of the century the indigenous iron had been crushed out of existence by the imported iron. By 1891-92, the quantity of imported iron was little below 2 lakh tons. The figure shows that the indigenous method of smelting pig iron gave only a precarious and supplementary means of subsistence to a small class of people in India.

Zinc was perhaps first discovered in India in the medieval period; reference to which are available from different *Rasaśāstras*. Zinc as an amalgam with mercury gave rise to *rasaka*. The large heaps of zinc and lead bearing residues, slags, clay retorts and fragments of furnaces found in *Zawar Area*[17] (in the state of Mewar, Udaipur) bear evidence that mining and smelting of zinc was traditionally known from the time of Lakh Singh, who mounted the throne at Chitore in 1383 A.D. Chemical analysis of slag has shown that metallic zinc and zinc oxide were recovered from zinc sulphide ores by a process that resulted in the waste product of glassy slag.

Captain Brooke who visited Zawar mines in 1844 and again in 1848 had outlined the general process of smelting of zinc ore. The retorts were first filled with ore and charcoal or other carbon bearing materials as a reducing agent. It was then capped with clay-cover and tube and then placed in an inverted position over perforated hearths. The retorts were then kept at high temperature by putting fire to the sorrounding coal with the help of blast of air set through the bottom of perforated hearth, through which the clay tubes were protruded downwards. The incoming air kept the tubes cool and the zinc metal and zinc oxide were deposited in the tube, since the temperature of the retort became high enough to distil zinc. When the process of distillation was completed, the condensing tubes were broken off, and zinc and zinc oxide were recovered. The smelting process was therefore basically similar to the pyrometallurgical zinc smelting technique used in England as late as 1854. In the present day technique, zinc sulphide ores are roasted before they are

placed in retorts, but it is not known whether this was actually done at Zawar.

The manufacturing of gold and silver ornaments by *soldering process* (joining together with alloys of tin and lead in varying proportions of copper and zinc) or *repousée process* (decorating of a metal sheet of gold or silver by carving designs in the reverse side and then turning the metal) were well known. These processes appear to have been practised in India from very early times. The manufacture of the glass of different colours was also current, since use of ear-rings among the Indian women were much in use.

The coal mining might have been known traditionally from ancient times. Large scale production started in 1854 when Dwarakanath Tagore took initiative to establish the Carr-Tagore Co., which was later named as Bengal Coal Company. The importance of coal began to be felt with the spread of western civilisation with its railways, mills and workshops. The number of mines rose to 87 in 1891, and the people employed were as many as 34 thousands including men, women and children. But the coal production was not in a position to meet the demands of the railways and other industries. The Company took measure to import coal from England. By 1894, the number of coal mines in India increased to 123 and the number of employed persons were as many as 43 thousands.

SOME MISCELLANEOUS TECHNOLOGY

The processes of the manufacture of paper, ink, soap, oil, etc. have been analysed.

Paper

According to some scholars, Arabs first learned the technique of manufacturing paper from the Chinese captives at Samarqand, and it is through them the *Kurasani paper* was first introduced into India in the 8th century A.D. According to others, Chinese paper came to India through Nepal between 7th and 9th century A.D. Ghori and Rahman[18], in their survey on paper technology in India has shown that the craft was more or less known in Medieval India. As to the technique of manufacturing paper, Captain Moor[19] (1790), who had intimate knowledge of the Maratha life, gives a description of paper making at Hurry Hal, situated on the eastern bank of Toongabhadra river. In a shallow well of 8 ft. diameter, a block of hard wood was fixed at the centre. The materials from which the papers had to be prepared were moistened with water for several days and then beaten to a pulp on the central wood by a heavy hammer or wooden beater. Old cloths, old tents, rotten gunny-bags, rags and such things were usually used, but when these things were not available, the bark of particular shrubs or *khaḍ* (hey) was mixed in proportion after these were washed well and soaked in water for several days. The pulp, after being sufficiently beaten, was mixed with little quantity of water in chunamed (limewater) reservoirs. A quantity of gum (from *bābul* tree) was also dissolved in the water. The moulds made of bamboo strips were then dipped into this mixture and the materials adhering to it when lifted out gave a sheet of paper after it was dried.

Buchanan in his *Patna Gaya Report*[20] gives a description of paper manufacture as prevalent in Bihar in the beginning

of 19th century. He says that wood instrument called *dhenki* was used for beating the pulp. The pulp was then bleached with soda water and washed, and the process was repeated six times. The bleached pulp was then put into a cistern with large quantity of water and diligently stirred with a stick. After an hour it was wrought off into sheets as usual.

The beating engine (Hollander) was first discovered by the Dutch between 1690 and 1720. This was perhaps a substitute of stamping or hammering technique known in different cultural areas. This is definitely the product of the industrial revolution in Europe which activated the large-scale operations. Moreover, Europe made some qualitative improvement of bleaching action by chlorine gas (discovered by Berthelot in 1785), or soda ash (by Leblanc in 1791) and paper making materials by the use of wood and special type of grass as pulp[21]. Buchanan, however, gives a list of 110 families of paper makers in Bihar who were engaged in this industry. Hodgson, British resident in Kathmandu in 1837 recommended Nepal paper for office use in place of paper of Hindustan for its quality. In 1841, British Government opened a factory at Darjeeling but closed it for it was found to be uneconomical. The paper industry by modern method sprang up only in 1862 when Girgaum paper mill was started at Bombay. By 1891, the number rose to eight, of which three were established in Bombay Presidency, three in Bengal, one at Gwalior and one at Lucknow.

Ink

The manuscripts of the 18th and the 19th century used golden, silver, black and red inks for writing of manuscripts.

The first two types of inks had been mostly used for royal personages and rich persons. The red ink is not suitable for eye and was used mainly for drawing boarder lines, geometrical designs, and beginning and end portion of the manuscripts. The most popular ink was of course black. Various methods of manufacturing ink both in solid and liquid form were known from ancient times.[22] Traditionally, black colour was obtained from *Kajjala* (soot), yellow or pigment from *haritāla*, white colour from *śaṅkha* (conch) powder, reddish brown from *darada* (red led), blood-red from *alaktaka* (red sap), dark red from *gairika* (red chalk). The techniques for manufacturing of black inks which were still prevalent in the period may be summarized as follows:

i) Roasted rice + lamp black + little sugar + (sometimes) juice of a plant called *Kesurte* (*Verbesina scandens*). (Mitra—*Notices of Sanskrit Manuscripts*, Vol. 3, p. 6). The labour of making this ink was great, for it required several days' continued trituration in a mortar before the lamp-black would be thoroughly mixed with the rice infusion. Otherwise, the lamp-black would settle down at the bottom in a paste leaving the infusion on top making it unfit for writing. Sometimes Acacia gum was also used to give a gloss to the ink, the ink was usually used for writing on the paper.

ii) Kesurte juice + decoction of *āttā*. The ink was used for palm-leaf manuscripts, absorbed into the leaf and could not be washed off. The ink is lasting and the gloss do not fade for centuries (Mitra—*Notices of Sanskrit Manuscripts* Vol. 3, p. 6).

iii) Soot (prepared by burning *kacalis*, coconut-halves or of *almonds*) + oil. This was used on the palm-leaf writing. First, manuscripts were scratched with an iron stylus having a pointed end, then the scratched surface was besmeared with the mixture, and lastly, it was cleaned by means of a cloth (*Jaina Citra Kalpadruma* by Muni Punya Vijayaji).

Various other traditional methods were known. Some of them used *picunand* (*nimba*), *bhṛṅgarāja*, *triphalā* (*haritakī*, *vibhītak* and *dhātri lākṣārasa* (lac-dye) *kāsīs* (green-vitriol, green sulphate of iron) etc. The inks both in solid and liquid form were in good demand during Mughal, Maratha, even British period, since their record department consumed large quantities of writing accessories. In Poona and Kolhapur, there exists still some Brahmin with surname *raktavān* which perhaps indicates their profession as ink maker.

Coconut or Mustard Oil

This is one of the most important village techniques by which mustard seeds or dried oily seeds of coconut were pested by a heavy wood or iron pestle. The iron pestle was usually fixed at the middle of a perforated wooden or metallic case. A circular motion of the pestle was created with the help of a fixed rod, one end of which was fixed to the pestle and the other end was attached to the ox effecting circular motion. This important and useful industry was prevalent in many places of West Bengal and Kerala and in some other places by the end of the nineteenth century and has now become obsolete with the introduction of large scale manufacturing technique. *Tilli*

and *Tambuli* classes are still in existence in different parts of Bengal for their association with the manufacture of oil.

Soap

The Portugese word for soap (*sābāo*) has been introduced into almost every language or dialect of the East. Kane[23] reports that the roots and crushed fruits of various kinds of soap tree had been in use in India for cleaning textile and impure articles. The term *sābuna* was first used by Guru Nanak[24] (1469-1538) who says (*Japaji Sāhib*) 'if the cloth gets dirty with urine, wash them with *sābum* (soap)'. It is not definitely known when the chemical preparation of soap was first introduced into India. Francis Buchanan in his *Patna-Gaya Report*[25] (1811-12 A.D.) first gives a report of manufacturing soap chemically in the company's factory at Bihar. The prescription is as follows:

Tallow (42 seers), linseed oil (15 seers), lime (2 seers) and impure soda (8 seers) were heated together to produce soap (84 seers). Each boiler produced 2 X 4 = 168 seers in a month and two families on an average were engaged for each boiler.

Buchanan reports that there were about 21 soap makers in the city of Patna and in the district of Berar. One Marathi MS., *Pes āvaicyā sāvalit*[26] (1773) prescribed *sāvan* and other materials against skin diseases. In the list of English goods being sold in Poona market in 1788, soap was mentioned as soap *vilāyeti*.[27] Soap industry thrived in India during the period and reached somewhat a prosperous stage at a time when foreign soap was being sold in the Poona market. Based on European methods, two factories came up at Merrat (Bihar) towards the end of 19th

century. In 1891, these two factories produced 9808 maunds of soap.

CONCLUSION

Apart from textile, metal-working, paper, ink, oil and soap, there were various other technologies, traditional or new, developed in the period. Some of these were printing, rice-cleaning, bone-crushing, rope-making, brewing, manufacturing of sugar, nitre, indigo, brick-making, lime-burning, potting, jute and leather technology etc. The technology associated with the industries of necessity of the villages and luxury industries of the town received little monetary support and faced almost no competition from outside except textile. On the other hand, the large scale manufacturing technique brought by British Raj made an important impact though indirect in the industrial as well as technological system in India. As a result of this impact, some of the manufacturing techniques have totally been vanished while some other have only been preserved with improvements and adaptations accrued from new technology, railways, opening of new roads, use of steam power etc. Several exhibitions[28] of articles manufactured with the aid of the machinery or according to scientific methods followed in Europe were organised in India by the end of the 19th century. One was at Cossipur (near Calcutta) under the auspices of the Indian Industrial Association of Bengal. The list of exhibits included pharmaceutical preparations, maps, looks, scientific apparatus, match, paddy, husking machine, surgical instruments, varnish, lamp, harmoni-flute, ink for polishing shoes, toys, biscuits etc.[28] This shows that India entered

into an intermediate phase of technological development by the end of nineteenth century.

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Techno-Cultural Study of Etched Beads from Tilaura-kot (Nepal)

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The ancient site of Tilaura-kot is situated about three-fourths km. to the west of the village Tilaura, which in turn is located $3\frac{1}{2}$ km. to the N.N.E. of Taulihawa, a District Headquarters in the central part of Nepalese Terai.

Excavations[1] conducted in 1962 has revealed a rich variety of beads made of semi-precious stones in addition to those prepared from other materials such as metal, glass, bone and terracotta. A number of partly worked beads, cores etc., indicate that bead-manufacture was a local industry. The excavator herself observes, "It is evident that lapidary art has attained a fairly high level. The lapidarist exercised ludicious selection of the material within their reach and improved on the natural form of the minerals by careful shaping with a sense for proportion and polishing. The bead-maker also exhibited a keen sence of decoration and great deal of skill in the manufacture of etched beads of chalcedony, agate and carnelian."

This paper[2] is concerned with the etched beads found at Tilaura-kot. The variety of patterns etched on beads,

though not many, yet the ones found, represent specific types. The place, being a centre of production, the decorative patterns found on beads, call for fresh comparative study, in contrast to those found elsewhere in similar chronological horizons. The main aim of this short paper is to study the patterns, their geographical extent and finally determine their cultural and chronological range.

The reasons for studying the etched beads from Tilaura-kot is to be stressed. Though, a number of sites have been excavated in the Gangetic valley in recent years, none of them have yielded such rich crop of etched beads, as at this place. Moreover the material has been published in full detail determining their cultural and stratigraphical range, which has made possible, now, to analyse the patterns in their correct chronological and cultural perspective.

Carnelian (nine beads), agate (eight beads) and chalcedony (three beads) seem to have been generally preferred at Tilaura-kot for etching of patterns. The use of all the three stones indicate the skill of the bead-maker, since, in general, carnelian and agate only were popular in the Early Historic Period, and the use of chalcedony also emphasize the successful experimenting the other finer stones for etching beads.

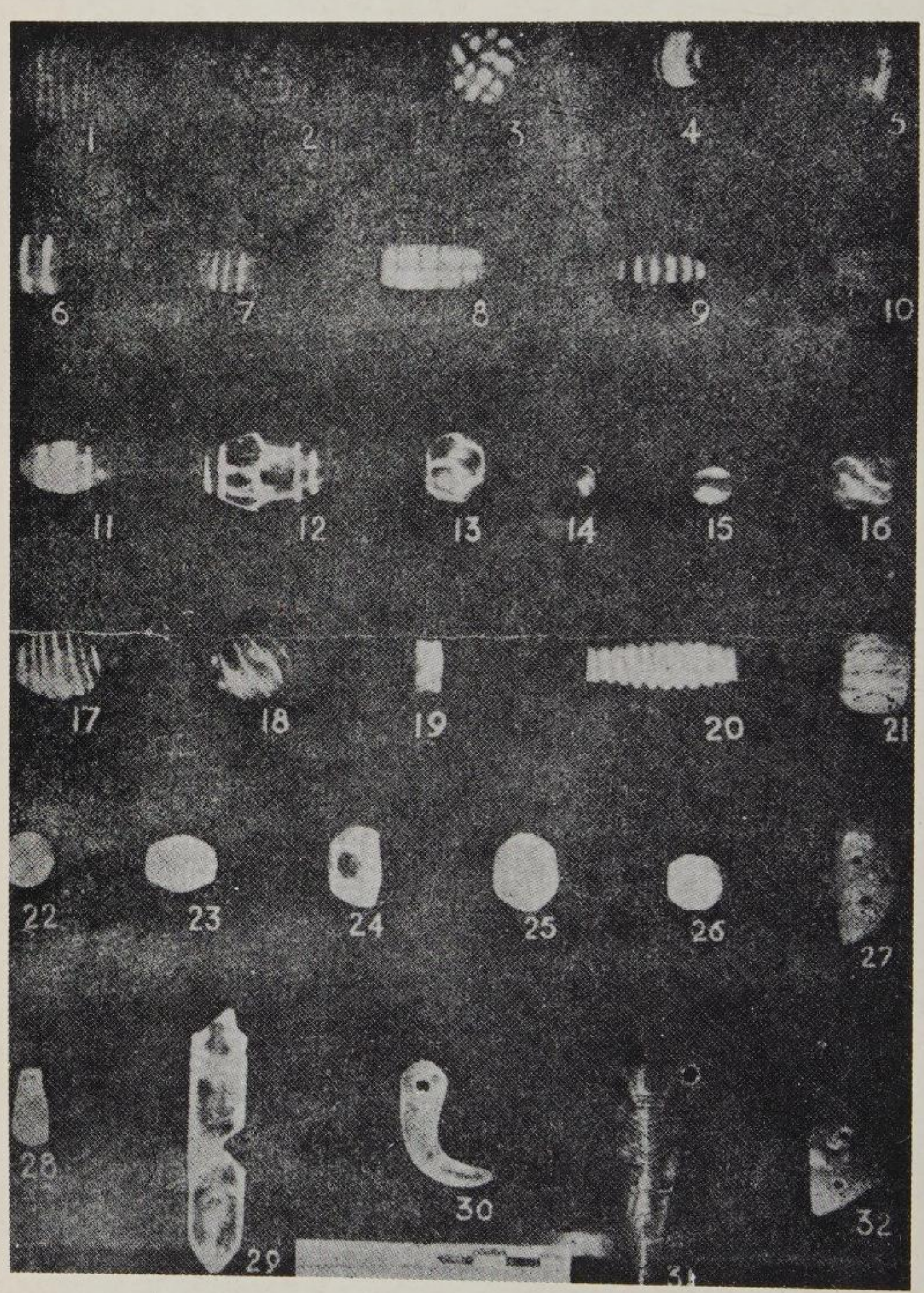
Most of the beads found here belong to Type 1 of Dikshit's[3] classification based on the method of their manufacture. Beads of this type are, by far the most common, exhibit white patterns on the natural surface of the stone. Out of the 21 etched beads found here, 18 of them have been etched in white on red background. One

of them has been found in which the design is in black on the whitened surface. This represents the Type II of Dikshit's classification. One another bead has been claimed by the excavator, that it bears the patterns based on the Type III technique in which the black pattern has been directly applied on the stone.

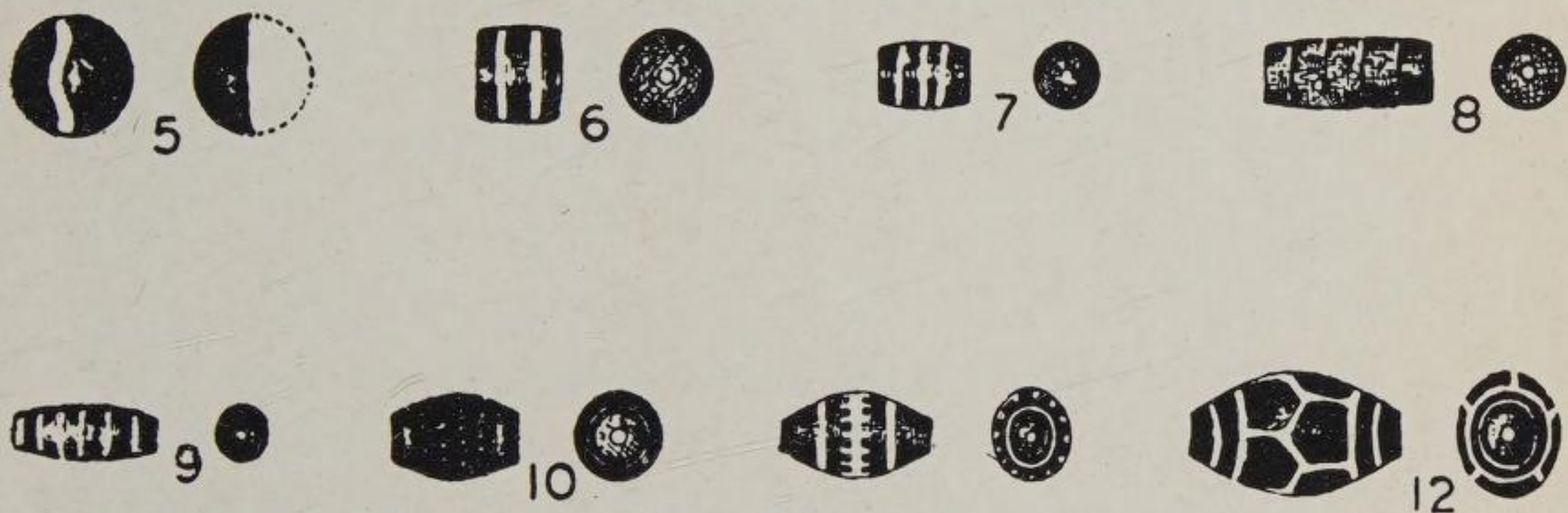
The evidence thus reveals that the lapidarists at Tilaura-kot were adopting all these processes in etching patterns on beads. The abundance of etched beads, but with select patterns reveal, the centre, as a localised industry perhaps catering to the needs of the local population of nearby places.

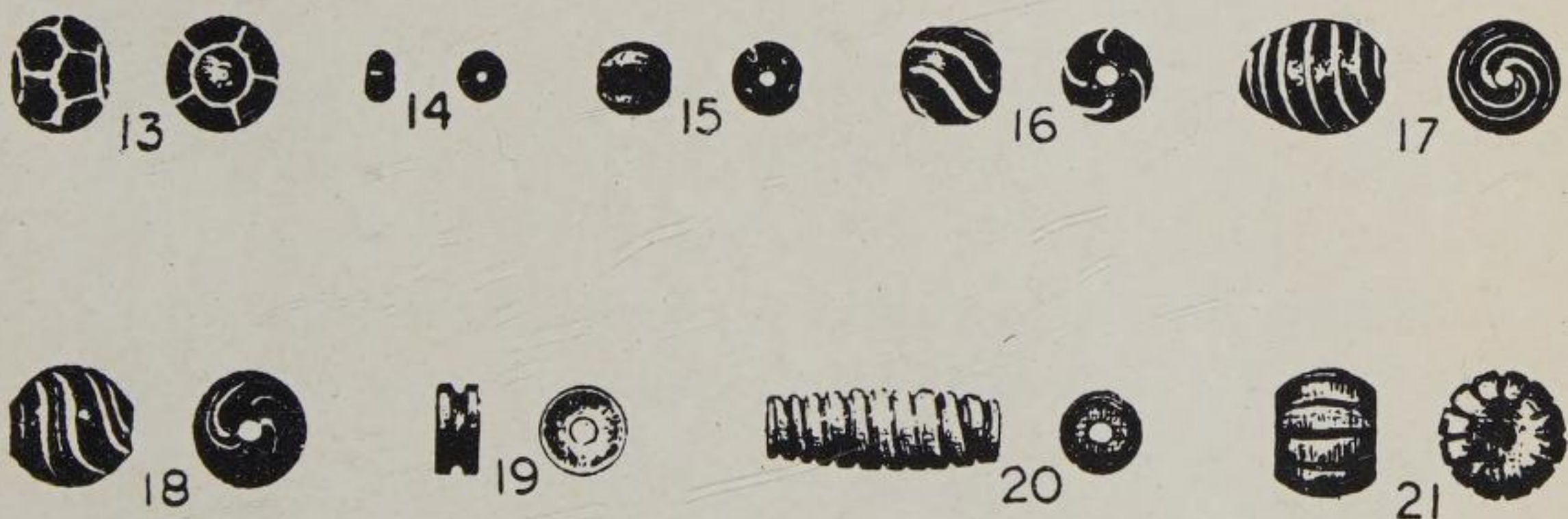
The decorative patterns etched on the beads are quite interesting. Five types of patterns of etching are found commonly used at Tilaura-kot. The sixth type is an eye bead, etched with a band, is not being discussed in this paper. All these five are, by far the most popular patterns used in heads in many of the sites of the Gangetic valley. Some of the patterns are common to all or some of the sites. The common patterns found here, are in general classified by Dikshit[4] as the Northern group of the Decorative Patterns which include "beads from several historical sites in the Gangetic Valley and on the North Western frontiers."

The classical site is Taxila[5] where all these patterns occur ranging in date from the fifth century B.C. at Bhir Mound to the first century A.D. at Sirkap, from which areas many of the beads were found. In the Gangetic Valley,[6] these beads occur mostly from surface and exploratory trenches of the sites dated on stylistic grounds to the early Historic Period from the third century B.C. to



Etched beads from Tilaura Kot (Nepal)





Etched beads from Tilaura Kot (Nepal)

the fifth century A.D. and in some even extend upto the Early Medieval Period (C.1000 A.D.).

Since Dr. M.G. Dikshit wrote his Monograph, *Etched Beads in India* quite a large number of new sites have been excavated and fresh evidences are coming in, which require a thorough study of etched beads from different sites viz., their technology, provenance and distribution. An attempt has already been made by the present author[7] elsewhere for the beads from Vidarbha and those from North-West Frontier.

Patterns etched on the beads at Tilaura-kot are of the following:

Pattern No. 1: Spherical beads etched with large number of minute dots all over the body in rows or in spiral lines.

Pattern No.2: Spherical or short cylinder circular beads decorated with zonal bands consisting of two, three, four or six bands.

Pattern No. 3: Spherical or barrel bead with pentagonal design within marginal bands.

Pattern No. 4: Barrel beads with three zonal bands, the central one being hatched with small serrated lines.

Pattern No. 5: Spherical bead with a wavy band.

All these patterns are discussed below in order and efforts have been made to situate them in proper cultural context.

Pattern No. 1: Spherical beads etched with minute

dots all over the body seems to have been the most popular pattern adopted in etching beads at Tilaura-kot. Nine of them found made from agate, carnelian and chalcedony. In six of them[8] (three in red agate, one in pink agate, one in carnelian and the sixth in brownish white chalcedony) the spots have been arranged in concentric circles (PL. I.1:PL. II.1) the number of the latter varying from five to eight; in another two of them,[9] (P.L. I.2; PL. II.2.) one in red agate and another in carnelian the arrangement of the dots are in spiral. The remaining one of carnelian[10] has a pattern (PL. I.3; PL. II.3) made by four sets of double convex lines (in dashes) converging at the extremities and enclosing two dashes within the resultant lenticular compartments. They occur in spherical shapes only and are datable to the third and early first century B.C.

At Taxila[11], this pattern has been found from the fourth century B.C. to the first century A.D. They are made from agate, carnelian and chalcedony, in type I and II processes in the technique of manufacture of beads. Rairh[12] has yielded them from the second century B.C. to the early Christian Era. At Alamgirpur[13] one of them has been reported from NBP phase. Kausambi[14] has yielded the patterns in levels of the first century B.C. In general, this pattern occurs in most of the sites of the Ganga Valley, recorded by Dikshit[15] datable on stylistic basis to the Early Historic period. Now only, for the first time, this pattern has been recorded from stratified levels at Tilaura-kot[16] which was consistently datable from the third century B.C. to the first century B.C.-A.D. Supporting evidence also comes from Alamgirpur, and Kausambi. Its occurrence at Rairh and Taxila suggest spread of this pattern towards

north and north-west, an aspect of the cultural diffusion by way of trade.

Pattern No. 2: Spherical and long or short cylinder beads decorated with zonal bands in rows of 2, 3, 4 or 6 bands.

This is also a popular motif adopted in etching at Tilaura-kot. Four beads were recovered here, while the fifth one has, in addition, more details. The first one is a standard, circular bead of carnelian[17] with the Zonal bands (PL. I.6; II. 6), the second is a long cylinder bead[18] with three bands (PL. I.7; PL. II.7) while the third is one is made of chalcedony,[19] a long cylinder bead, having four colourless grooves, (PL. I.8; PL. II.8) while the fourth one is also of chalcedony[20] (PL. I.9; PL. II.9) having six bands. Very close to this pattern is a barrel bead of carnelian with six zonal bands[21] (PL. I.10; PL. II.10) in greenish black, the central four consisting of dots instead of bands.

The method of etching was chosen and dexterously used in spreading this pattern in such a small space indicate, the mature handwork of the craftsmen of the times.

This type has been reported extensively from many sites, in datable contexts. At Tilaura-kot itself, it occurs in levels of c. the third century B.C. and later. The earliest 'Zone' bead, as it has been called by Beck at Taxila[22] goes back to the fourth century B.C. It is of carnelian. Another one of agate[23] comes in levels of the first century A.D. Both of them have three zonal bands.

Apart from this, it occurs at Kaundinyapura[24] in Megalithic levels in large numbers. They consist of two

varieties. One of them has zonal bands[25] at regular intervals all over, while the other has three zonal lines[26] forming a band in the centre of the bead. Similar patterns are also found in beads of Khapa[27] and Takalghat,[28] both being spaced at regular intervals. In this context, Dikṣhit adds, "these barrel-shaped beads belong to a class of beads which were popular in many parts of India during the Early Historic Period and in certain cases, in an admittedly Megalithic context".[29] Identical patterns also occur on beads from Maski[30] datable to the early centuries of the Christian era. One comes from Navda-Toli[31] also.

An etched bead of this pattern in carnelian comes from Nagal[32] (District-Broach) in levels of the second century B.C. All these sites are situated in central and western India.

Nearer to Tilaura-kot, a few sites in the Gangetic valley have yielded this pattern in definitely datable contexts from the Early Historic levels. The earliest of them occur in NBP Ware-phase at Kausāmbi,[33] Rājgir,[34] and Śrāvasti[35] from about the third century B.C. and later. Kumrahar[36] has yielded them between the first and fourth centuries A.D. They are made in agate etched with bands varying from one to six. At Śrāvasti also, beads, made in agate were found, where as at Kausambi, they were prepared in carnelian. Specimens at Ahicchatra[37] continue to be found upto the medieval times.

In addition Dikshit[38] records a number of sites in the Gangetic Valley which have yielded beads of this pattern.

The evidence reveals, that this pattern has been reported in NBP—Phases in the Gangetic valley, in fourth

century B.C. levels at Taxila as well as in the Megalithic levels of Central India. The origin of Megaliths in Vidarbha has been suggested to go back to the early first millennium B.C.[39] The early occurrence of this pattern in beads from Pre-NBP-Megalithic habitation suggests, that it is an earlier variety from Central India which spread later on to the Gangetic valley and North West. Its wider availability in sites of Gangetic valley from NBP levels to the first century A.D. supports the diffusion of this pattern to the North. It continues to be popular in early medieval times, as the Ahicchatra evidence testified.

Pattern No. 3: Spherical or barrel bead with pentagonal design in marginal bands. This pattern occurs at Tilaura-Kot[40] from the third century B.C. It is found both in barrel and spherical shapes, three of them belong to the former and one to the latter. The barrel beads comprise one in black agate,[41] (PL. 1.12; PL. 2.12) another in red, while the third is of carnelian, but broken the last one has two connected rows of five pentagons each, with a marginal band near the ends. The second pattern without marginal bands comes in spherical shape,[42] (PL. 1.13; PL. 2.13) made from banded black agate.

These correspond to patterns No. 6, 6A (in spherical) of Dikshit's[43] classification of etched beads, essentially coming from Early Historical sites of North India. Since Dikshit wrote his Monograph[44] many sites in Central and Western India have yielded beads etched with this pattern, overlapping the area of North and South group boundaries fixed by him. Significantly, most of them come from Satavahana levels of c. the second century B.C. and second century A.D.

For this pattern, barrel-shaped beads seem to have been preferred for the spherical one.

Barrel-beads with this pattern (No. 14 of Dikshit's classification) occur from Mauryan times onwards at Ahicchatra[45] Hastiṅapura[46] Nasik,[47] Rajgir,[48] Taxila,[49] and Tripuri.[50] They are common from the second century B.C. to the early centuries of the Christian era at Bahal,[51] Kausambi,[52] Nagri,[53] Rairh,[54] Sambhar,[55] Sonkh,[56] Taxila[57] and Ujjain[58]. All of them have been found from regular stratified levels. Dikshit[59] reports a number of beads from surface in the Gangetic valley.

The early spherical beads (pattern Nos. 6, 6A) have been reported from Ahicchatra,[60] Bangarh,[61] Rajgir,[62] and Taxila[63] from Mauryan levels. Similar ones also occur at Maski[64] and Rairah.[65] In addition, Dikshit[66] lists many sites in the Gengetic Valley.

The prominence and wider diffusion of this pattern from the Gangetic valley to the Central and Western India and Northern Deccan, as well, as the North-West is quite significant. It spreads from about the second century B.C. and by the early centuries of the Christian era, it has been reported from many sites, specially in Central India and Northern Deccan. What induces to make popular this pattern, in various bead-manufacturing centres is not known, but this fact can be attributed to the growing contacts between North and South India by way of trade and commerce and the opening of a number of trade-routes (*Śārtha-vāhapathās*) in the Early Historical times. Dikshit[67] significantly ascribes the migration of this pattern due to the advent of the Satavahanas in Central India.

Pattern No. 4: Barrel-shaped beads with three zonal bands, the central one being hatched with small serrated lines.

At Tilaura-Kot[68] only one bead of carnelian (PL. I. II; PL. II.11) comes from the levels of the third century B.C. It is a popular pattern in beads found in Gangetic valley sites from the early Historical levels.[69] It occurs both in beads of Type I and II. Dikshit[70] points out they are found in barrel beads, in general. Two sites have yielded this pattern on beads of spherical shape. One is from Taxila[71] of agate datable to the first century B.C. Another comes from Ujjain.[72] Its occurrence at both these places apart from Gangetic valley sites, though isolated finds, may have reached by way of trade contracts. More material evidence is needed to ascertain its origin.

Pattern No. 5: Spherical bead with wavy bands around.

An agate bead (PL. I.5; PL. II.5) comes from Tilaura-kot[73] etched with this pattern closely following the natural whitish band in the bead, datable to c. the third-second century B.C.

Beads with this design occur at Taxila[74] from the fifth century B.C. to the first century A.D.

This pattern has not been recovered from any other site in the Gangetic valley, known so far. Significantly quite a few of them are found from Central Indian sites. One specimen of this type comes from Khapa.[75] Identical decoration is to be observed on a bead from Kauṇḍinyapura[76] datable to the Śātavāhana times. A specimen has been picked up from Paunar[77] having this design.

Its availability at the above sites, especially in Vidarbha region of Maharashtra is a fact to be explained, either by reason of trade or commerce or any early origin in this area itself. Its occurrence at Khapa in Megalithic levels supports this evidence. So far this pattern has not been reported in South Indian Megaliths.

Only five patterns occur at Tilaura-kot which have been analysed above, basing upon the latest published material evidence reported from many ancient sites.

An emerging fact is to be stressed. Ornamentation on heads for decoration seems to have been popular in all ancient sites of the early Historic Period. The patterns available at Tilaura-kot in comparison with those available elsewhere, in contemporary chronological contexts, reveal, that the pattern Nos. 2, 3, 5 had a wider distribution in space and time, than it was thought to be otherwise, previously. Their occurrence in early Megalithic levels in Central India and NBP ware levels in the sites of the Gangetic Valley, suggests, a re-thinking, as to their early origin, as well as to the problem of their distribution in space and the boundaries fixed by Dikshit. For the first time pattern Nos. 2 and 5 occur in the Megalithic levels of Central India datable as per the latest evidence, to the earlier part of the first millennium B.C., probably earlier to their occurrence in the Gangetic valley. But this suggestion is to be corroborated by more material evidence from recently excavated sites. In the meanwhile, Tilaura-kot evidence of etched beads, adds, a significant contribution to the material remains on a rare aspect of a problem of the Early Historic Period.

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Technology of Transport Vehicles in Early India

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INTRODUCTION

The main vehicles of transport on land consist of simple carts drawn by bullocks, wagon vehicles, chariots, etc. Excavations have not revealed remains of parts of actual carts or any other wheeled vehicles. As they were made mostly of perishable materials such as bamboo, wood, leather, etc., they have not withstood the ravages of time. On the other hand, a large number of miniature vehicles have been reported from a number of sites giving an insight into the technique of their manufacture and use. These model-carts were perhaps used by children as toys and at the same time testify to the skill of the toy-makers.

This paper deals mainly with the transport vehicles of the early historic period, c. 300 B.C. to A.D. 300. Most of the evidence comes from sites in central and western India and the Deccan, with the exception of a few sites in the Ganga Valley.

As an introduction, the earliest evidence from the

Harappa sites may be described to give a general outline of the evolution of transport vehicles. The actual material evidence is quite meagre to make any positive statements. Only during the early historic period does the evidence reveal an abundance and variety of transport vehicles which speaks of the technology of their manufacture.

TOY-CARTS

The earliest toy-carts with and without wheels and frames have been reported from Chalcolithic times at Alamgirpur (IAR, 1958-59), Chanhu-daro (Mackay, 1943), Harappa (Wheeler, 1947), Kalibangan (Lal and Thapar, 1967), Lothal (IAR, 1955-56), Mohenjodaro (Marshal, 1931) etc.

These are comprised of cart-frames made of terrocotta with four vertically pierced holes on each side to take stakes of wood. The four holes at the middle took longer stakes, which projected from the underside of the frame in pairs, between which the easily removable axle of the wheels was held. There were also horizontal holes for the shaft through one end of the frame and the middle cross-piece. With a floor of matting or rope-work the open frames of these carts were well-adapted for carrying goods and passengers.

Apart from these, not much is known about transport vehicles during the Chalcolithic period.

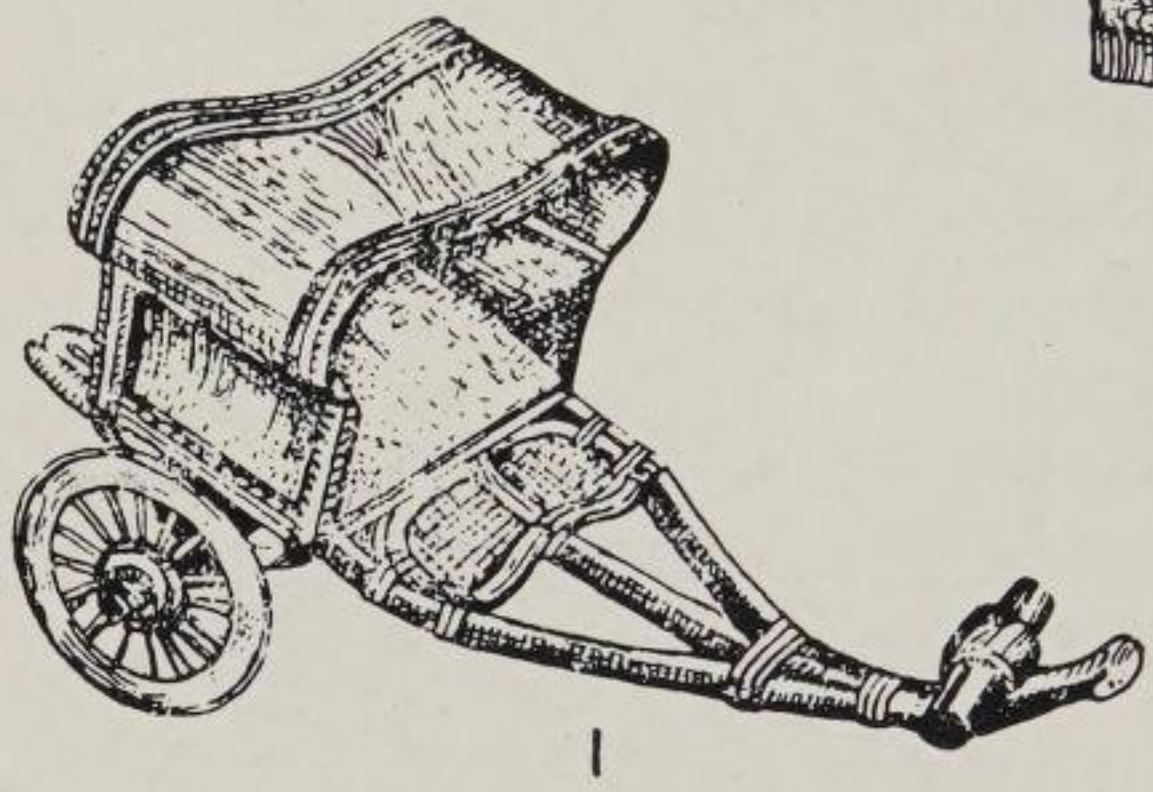
The available evidence of cart-models during the early historic period indicates a wide range of transport vehicles of the times. They were quite different from those found from Chalcolithic levels. Some of the model-carts are

quite simple. Others are covered wagons and quite a few represent chariot-models. The coverings seem to have been made of some material such as a framework of light bamboo or a leather cover. The workmanship of the cart and the accuracy in details indicate a very commendable level of skill in the casting and fashioning of artistic metal objects as well as modelling in terracotta.

The toy-modles and cart-frames are almost identical with those of modern times. Their salient features can be enumerated from the toy-models reported at Atranjikhera, Brahmapuri, Charsada, Rairh, Rangmahal, Sambhar, Taxila, etc. They are made of copper or bronze or terracotta.

Toy-cart models at Rairh and Taxila are reported from c.300 B.C. Many of the Taxila ones are made of terracotta. They consist of toy-carts drawn by animals e.g. horses, bulls, rams and also birds (Marshall, 1951). One of the chariots has a transverse hole for the axle underneath the body and another hole for the pole in front. The wheels of the chariots show heavy and clearly defined hubs and fellies, whereas the later specimens from Sirkap show hubs, but not raised fellies. At Charsada (Wheeler 1962) part of a terracotta toy-cart is a unique specimen having a neat finish with holes pierced through the body for the poles.

Rairh (Puri) has yielded model chariots made of bronze. Both of them are very neatly made with a clear finish. One of them (Fig. 1:3) has the yoke left open at the back and provided with high sloping and voluted sides. Another (Fig. 1:5) is without yoke open at back but provided with clear mud-guard-like projections on the sides. It is fitted



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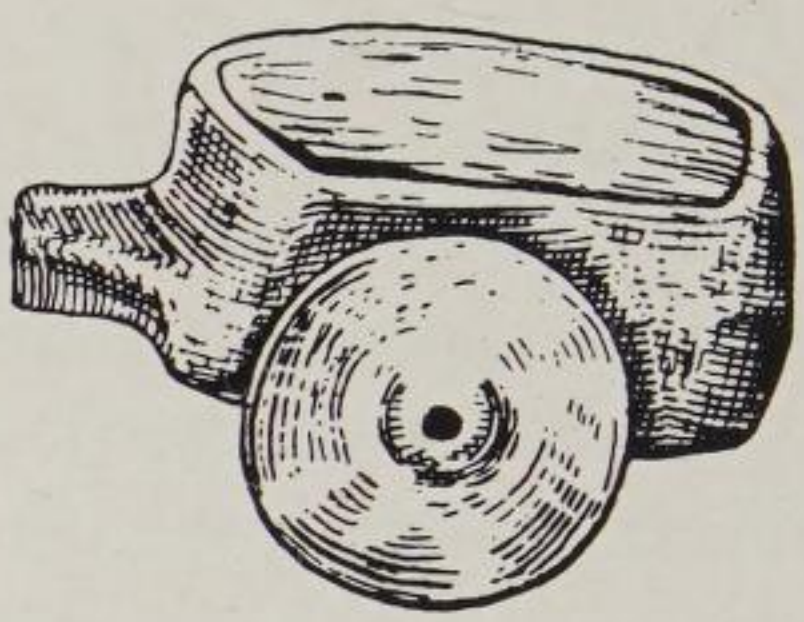

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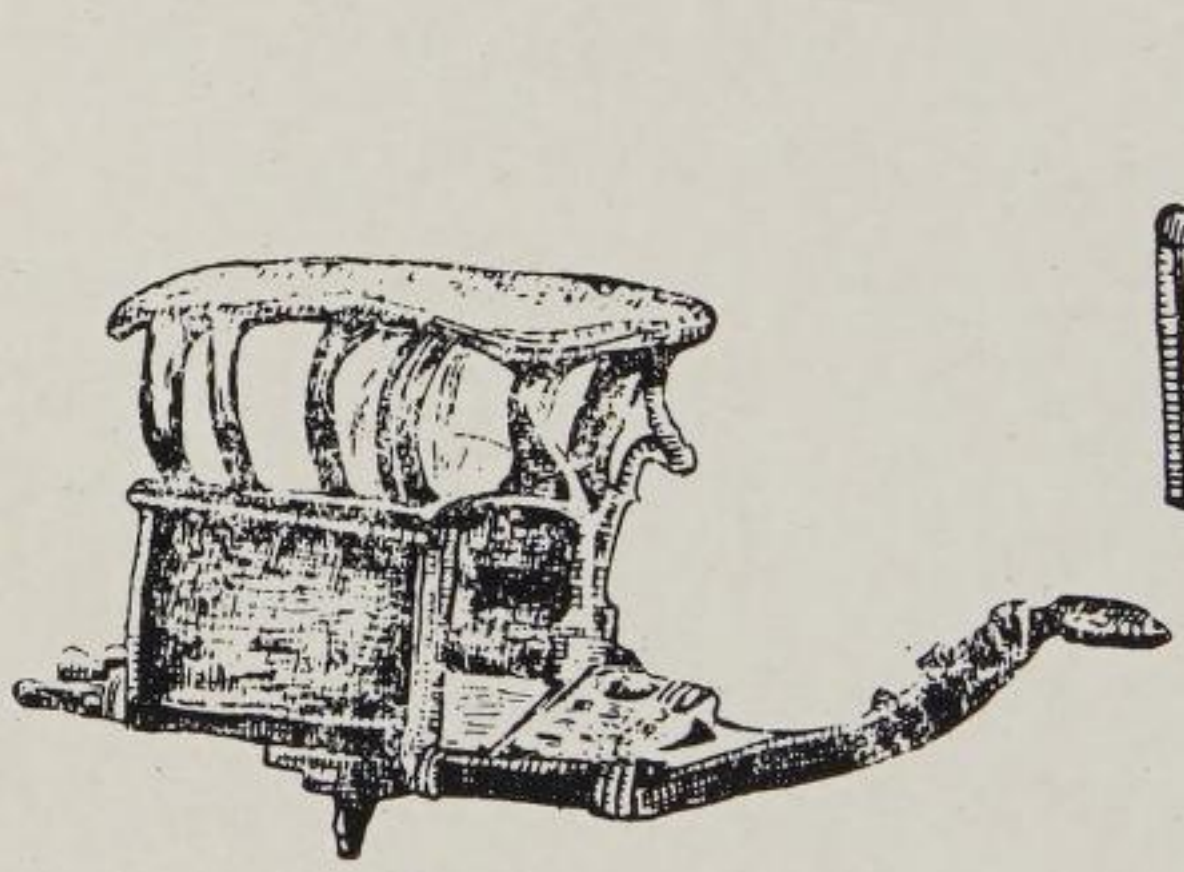

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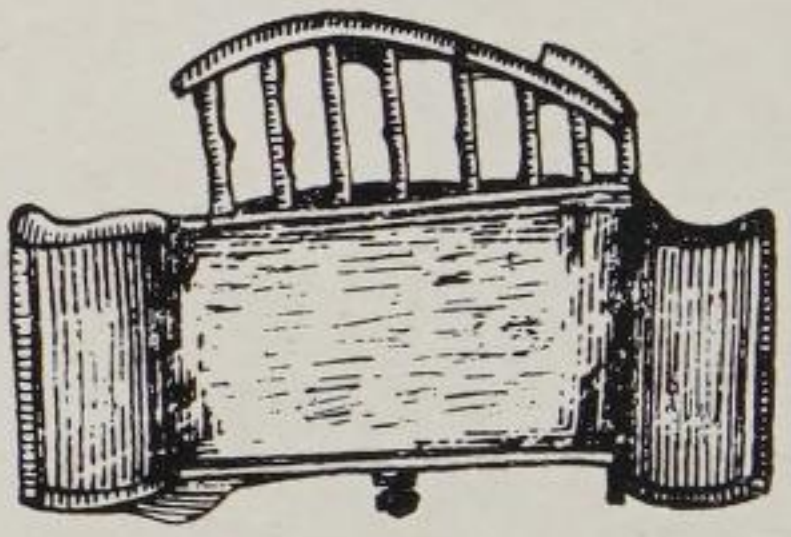

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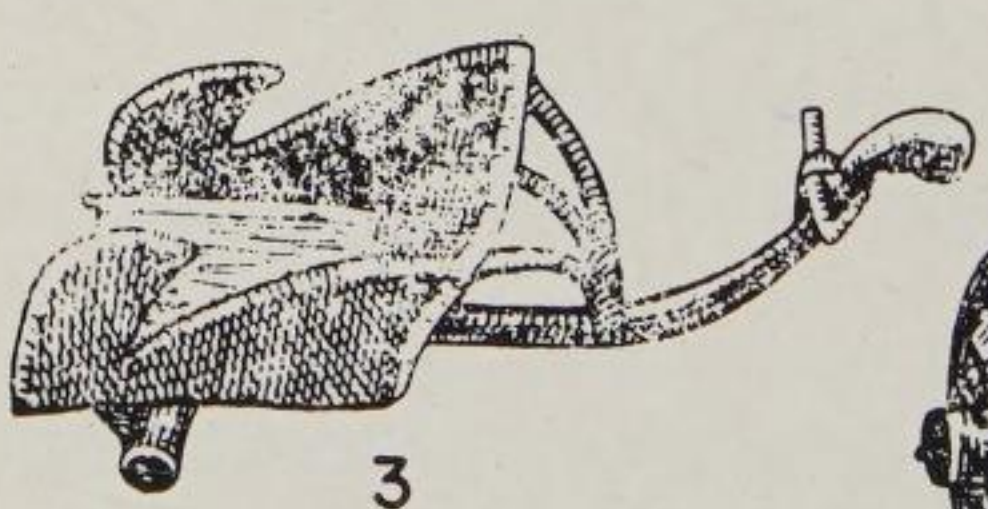

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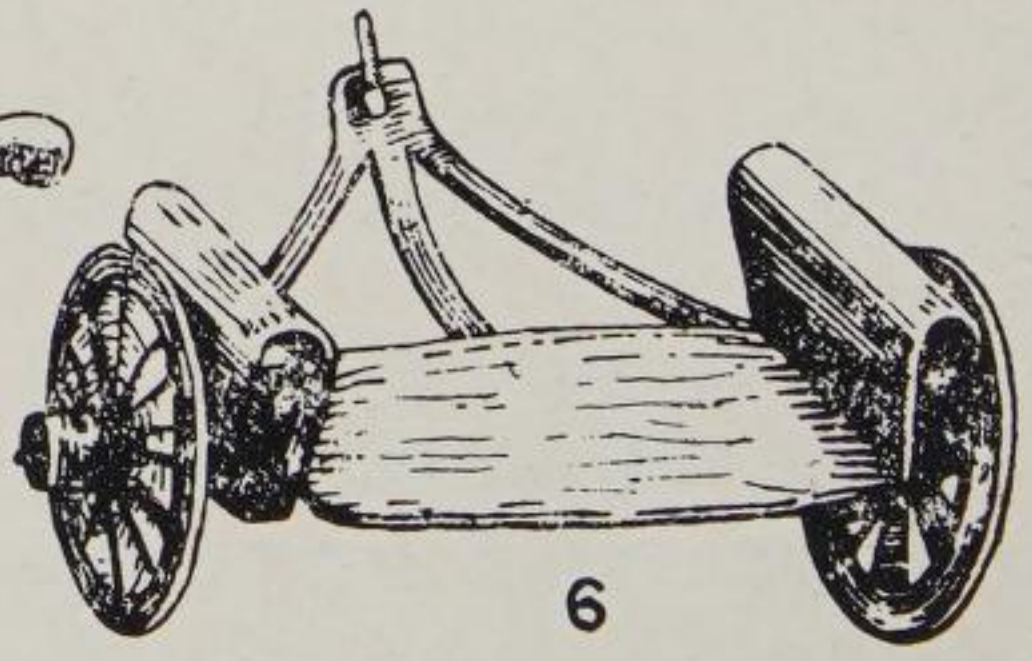

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Fig. 1. Cart models: 1, 2, Brahmapuri (copper); 3, 5, Rairh (bronze); 4, Sambhar (terracotta); 6, Taxila (copper).

at the back with a circular projection composed of 11 bars, an arrangement which kept down the weight of the chariot with the additional advantage of providing more space for sitting or for luggage. They have no canopies. A specimen in terracotta is exactly similar to one from Taxila.

At Atranjikhera (IAR, 1962-63) one of the finest model toy-carts (PL. XI) with wheels has been assigned to the Sunga period. It is an open vehicle with two wheels having hubs and spokes. It has been tastefully decorated externally with flower patterns divided into three rows by three poles. The details of the front part and the yoke are missing.

Two interesting toy-carts of copper from Brahmapuri (Khandalawal, 1960) come from Satavahana levels. Both are covered wagons (Fig. 1:1 and 2). Both of them are probably accurate copies, in practically every detail, of the covered wagons of those days. They throw light on the means of transport quite apart from their significance as toy-models. Each of the two carts is intended for a pair of bullocks. The coverings may have been of a light bamboo screen.

Amongst carts depicted in the stone reliefs of Amaravati and Nagarjunakonda, one covered wagon (Barrett, 1954) is similar to the above type. In both, the ribbing which supports the top cover of the cart is curved and twisted. Another relief at Nagarjunakonda (c. 300 A.D.) has been carved with a horse on wheels and a toy-cart (longhurst, 1938). A simple terracotta model cart was found at Hastinapura (Lal, 1954-55) in levels of c. 200 B.C. and after. It is an open two-wheeled cart with a hole at the yoke end

for fastening a string to pull the cart. Vertical poles were strung with horizontal bamboo screen, which perhaps covered the top. A contemporary specimen form Noh (IAR, 1965-66) is also of terracotta, but no details are known. Many toy-cart models have also been reported from Nagarjunakonda (IAR, 1956-57), Ujjain, etc., but their details are not yet published.

A terracotta specimen from Sambhar (Daya Ram Sahni) is a realistic model of the Kushan times. It is an open toy-cart with raised sides, perhaps for the passengers to sit, with two wheels and holes pierced at the bottom to accommodate the axle-rod (Fig. 1:4).

Some interesting cart-modes have been reported from Sirkap (c. A.D. 100) made of copper and terracotta. The copper one (Marshal, 1951) is an exquisite model of the type in vogue during the period. It is a two-wheeled vehicle which 'appears to be a sort of light racing chariot' (Fig. 1:6). Marshall (1951) is of the opinion that it is quite different from the typical Indian chariot current during this period and was perhaps a foreign type introduced by the Parthians. But similar and identical wheeled carts have been reported from Brahmapuri, from Satavahana layers. There is only one difference between these two; the carts from Brahmapuri are covered wagons, the poles having been strengthend by diagonal stays. Marshall's statement of how the chariots and carts were drawn has been amply corroborated by the specimens from Brahmapuri, wherein the horizontal pole was used as a yoke to tie two bullocks to draw the vehicle. It is quite likely that these carts belong to an indigenous type.

At Sirkap (Marshall, 1951) terracotta carts represent a

sort of simple light vehicle, viz., a 'dog cart' furnished with two holes in front for the shafts and two grooved projections underneath for the wheeled axle. Rangmahal (Rydh, 1959) has yielded carts of terracotta from the late Kushan levels. One of them is a fragment of a toy-cart and represents the back part with a transverse hole for the yoke to pass through. The other is a part of the body. These are open carts pulled by one or two animals, as seen even today in these regions. At Yeleswaram (Khan, 1963) terracotta toy-carts are known from the Ikshvaku levels.

Apart from the toy-models described above, an interesting moulded-medallion of terracotta from Ujjain (IAR 1956-57) bears the impression of a chariot. It has been assigned to the Sunga period or later. The sides of the vehicle are decorated with flower-patterns. It is identical to the cart-models found at Brahmapuri and Atranjikhera.

WHEELS OF TOY-CARTS

Wheels without toy-carts have been reported in abundance. Though all of them are toy-wheels for model carts, they reflect the nature and growth of actual wheeled vehicles and means of transport during the early historic period. Some of the wheels are plain and devoid of decoration. Many of them are found with their other parts, for instance, spokes, hubs, etc. It is quite clear that hubbed and biconvex wheels become a common feature in the transport of this period. Hubbed wheels have a decided advantage inasmuch as they are reversible in fitting and cause less friction with the body of the vehicle.

The earliest wheels, reported at Mohenjodaro (Marshall,

1931), have hubs only on one side. At Chanhudaro (Mackay, 1943) all the types have been reported: single hubbed, biconvex, plane-sided, etc. The toy-wheels in the early historic period are both in bronze and terracotta.

Though wooden wheels have not been reported, the terracotta specimens definitely imply the existence of large wooden carts. Wheels are prepared in a number of ways. Some are modelled, while a number of them are made from moulds. Many of them are also made from potsherds rubbed into shape. The hub is in general indicated in relief, while the spokes decorated by concentric circles are slightly incised.

Some of the specimens (c.400-200 B.C.) at Nasik (Sankalia and Deo, 1955) have straight, curved or elongated cross-sections. One of the wheels has been decorated with spiral-like embossed circles. Contemporary ones with and without hubs at Awra (Trivedi, 1962) continue to be used in later times also (c. A.D. 300-500).

At Charsada (Wheeler, 1962) they were found with hubs on one side. Some, dated to Mauryan times, are cogged and smooth-tyred. Some of the finest bronze wheels are known from Rairh. One has 11 spokes fitted to an axle that passed through the rings provided beneath the body of the chariot. These wheels give a vivid idea of the types of the chariots which were in vogue during Mauryan times and later. The wheels and frames were found separately but fit well with each other. Apart from those of bronze, many terracotta ones were found here with hubs, central holes and spokes.

Wheels occur in abundance in c.200 B.C. levels and

later. At Amreli (Rao, 1966) they are made from moulds and also modelled by hand. In a few the hub, rim and spokes are indicated in relief. A number of them at Maski (Thapar, 1957) are made from pot-sherds, whereas at Besnagar (Arasi, 1914-15) and Paithan (Aradnd, 1936-37) they are made from moulds. Wheels at Besnagar have been found with hubs on both sides. A variety of shapes of wheels has been reported at Nevasa (Sankalia *et al.*, 1960). Some are thick with a rectangular section, and a few have prominent hub on one side. Others are biconvex with truncated hubs on both sides. Quite a few have no hubs at all. They come from *c.* 150 B.C.-A.D. 200 levels. The wheels from Ter (Chapekar, 1969) include solid ones with a biconvex section and a central perforation. Different varieties of wheels occur at Ujjain (Aaaradgs, 1938-39) in similar horizons. They have been tastefully decorated with hubs, wheels and spokes, perhaps prepared from moudls and later ornamented.

Wheels occur in large numbers at Amreli (Rao, 1966) in the early centuries of the Christian era. One of them has been decorated with pellets on the rim but it has not central perforation. At Salihundam (Subrahmanyam, 1964) pottery wheels are found in Ikshvaku levels. Solid wheels with projecting hubs on both sides come from Baroda (Subbarao, 1953) and Sambhar. At Eran (Iar 1964-65) and Karvan, they occur in levels of the early centuries of the Christian era. Many of the finest specimens are known from Rangmahal. A number of them have hubs on both sides, while a few have hubs only on one side. Some are biconvex-shaped, while other have spokes decorated with pellets, dots and lines in relief. All these wheels suggest the prevalence of terracotta cart-frames also. The

gradual development from the simple to the complex types of wheels can also be visualized from the specimens.

CONCLUSION

The foregoing analysis of model-carts and wheels clearly testifies to the real transport vehicles during the early historic period. It may be noted that the vehicles of the early historic period are more advanced than those reported during the chalcolithic times.

Three types of wheeled vehicles are revealed by the available evidence.

The simple vehicles were some sort of *ekkas* of the present-day drawn by a single animal. The more developed ones were provided with sides for the passengers to sit and drawn by two animals. Some of them were tastefully decorated. The finest and most advanced type was the chariot or the wagon vehicle provided with a raised canopy used both for passenger and goods trafic. They were perhaps drawn by two or more animals. All these were very likely the common types of vehicles for transport used by the general public. In a way they give ample testimony to the varied nature of transport during the early historic period.

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13

Shipping in Ancient India

(from the earliest times to 600 A.D.)

S. R. RAO

The great land-mass of the Indian subcontinent is sea-girt on the east, west and south and has a large number of sheltered harbours situated all along its 5,700 km-long indented coastline. It is generally believed that the inhabitants of this land-mass lived in isolation and were afraid of undertaking sea-voyages. This belief has arisen because of the religious injuctions against *samudrayātrā* (sea voyage) in the case of certain sections of the Hindu society. But a careful examination of the passages in the *Ṛgveda*, confirms that the Indians went into the open sea boldly. Recent archaelogical discoveries have also brought to light the actual remains of brick-built docks, wharfs, jetties (landing platforms) and warehouses ranging in date from 2300 B.C. to 300 A.D. These structural remains bear ample testimony to the skill of the Indian seamen and engineers in building ships and docks and corroborate tradition and literary evidence.

Before attempting a survey of the archaeological evidence, it is necessary to know what the vedic texts have to say about sea-voyages. The Vedic texts themselves

do not discourage sea-voyage. On the other hand the references in the *Ṛgveda*, *Śatapatha Brāhmaṇa* and other texts clearly show that our ancients did undertake naval expeditions and travelled to distant places by sea-routes well known to them. In the *Ṛgveda* for example, God Varuna is credited with the knowledge of the sea-routes followed by ships (1.25.7). The same text further adds that merchants used to send out ships to foreign countries (2.48.3). A naval expedition is also said to have been sent out by the Ṛiṣi-King Tugra under the command of his son Bhujyu. The ship was, however, wrecked in a storm, but some of the occupants including King Tugra and his followers were rescued by the Aśvins, the twin brothers, who came in their hundred-oared galley. Another passage in the *Ṛgveda* addressed to Agni says : "do thou convey us in a ship across the sea for our welfare". Three things emerge from these references. First, ships were sent to foreign countries for purposes of trade; second, multi-oared boats were used in expeditions, and third, sea-routes were known to the Vedic Aryans. We shall examine each one of them in the light of archaeological evidence obtained recently.

In this article we confine ourselves to the history of shipping in India from the days of the Indus Valley Civilization to 600 A.D. covering roughly three thousand years. For purposes of convenience this period is divided into two sub-periods, viz., the Protohistoric (2500 B.C. to 500 B.C.) and the Early Historic (500 B.C. to 600 A.D. with further subdivisions in each sub-period. At the end we shall also refer to the ship-building industry and the organization of commerce in ancient India. The sources of information are extremely limited for the Proto-historic

period. The archaeological evidence so far obtained consists of the actual remains of a dock at Lothal and a number of trade-mechanisms, tools and ornaments exchanged between the Indus and Sumerian Civilizations. So far as literary evidence is concerned we are very much handicapped by the non-decipherment of the Indus script and the failure to identify the authors of the Indus Civilization. The references in the Vedic texts and the Epics to the Aryan and non-Aryan sections of the population and their maritime activities are limited in nature, and still remain to be corroborated by archaeological finds. On the other hand we are flooded with literary references to shipping and maritime trade of the Indians in the early historical period. The Buddhist Jātaka stories, the Jain canons, the *Arthaśāstra*, a highly valuable treatise on political economy in the Mauryan period, the mariners' guide-book known as the *Periplus of the Erythrean Sea* (50 A.D.), and the works of the early Greek writers such as Pliny (1st century A.D.) and Ptolemy (2nd century A.D.) furnish vluable information regarding sea-borne trade, the types of ships in use and the cargo handled at various ports. Overseas and inland trade-routes and the trading centres are graphically described in the works of foreigners. Unfortunately very little work has been done archaeologically to unearth the remains of ancient ports on the Indian coast and to salvage ship-wrecks, if any, in the Arabian sea and the Indian ocean. Much scientific progress has been made by American universities in underwater archaeology and ship-wrecks of the Bronze Age and Roman period have been salvaged in recent years near the Turkish coast. If similar expeditions are undertaken in India there is little doubt that thrilling discoveries can

be made and a chain of port-installations all along the western and eastern sea board ranging in date from 2200 B.C. to 1500 A.D. can be identified.

PROTOHISTORIC PERIOD

Maritime Activities of the Harappans

(i) The Port-city of Lothal:

For reconstructing the history of India from the earlier times one has to begin with the Indus Civilization, but unfortunately as a sequel to the partition of India all the important sites to this civilization went over to Pakistan. Hence arose the necessity of finding Harappan (Indus Civilization) sites within the present borders of India. A systematic survey of the Ghaggar (Sarasvatī) valley in the north and the Kathiawar peninsula in the south was undertaken by the Archaeological Survey of India between 1953 and 1958. The exploration resulted in locating more than two dozen Harappan sites by A. Ghosh in the Bikaner division of Rajasthan and nearly 100 sites by the present writer and late P.P. Pandy in Gujarat (including Kutch and Kathiawar). Among them Lothal is the most important especially because it was a port-city contemporary with Harappa and Mohenjodaro. The site was discovered in 1954 and excavated on most scientific lines between 1955 and 1962. Lothal is situated at the head of the Gulf of Cambay at a distance of 80 Kms. south-west of Ahmadabad (Fig. 1). Here was a well-planned city with neatly laid-out streets, underground drains and a large artificial dock built for berthing ships. The city was divided into two parts namely the Acropolis and the Lower Town (Fig. 2), the former being occupied by the ruler and the latter by

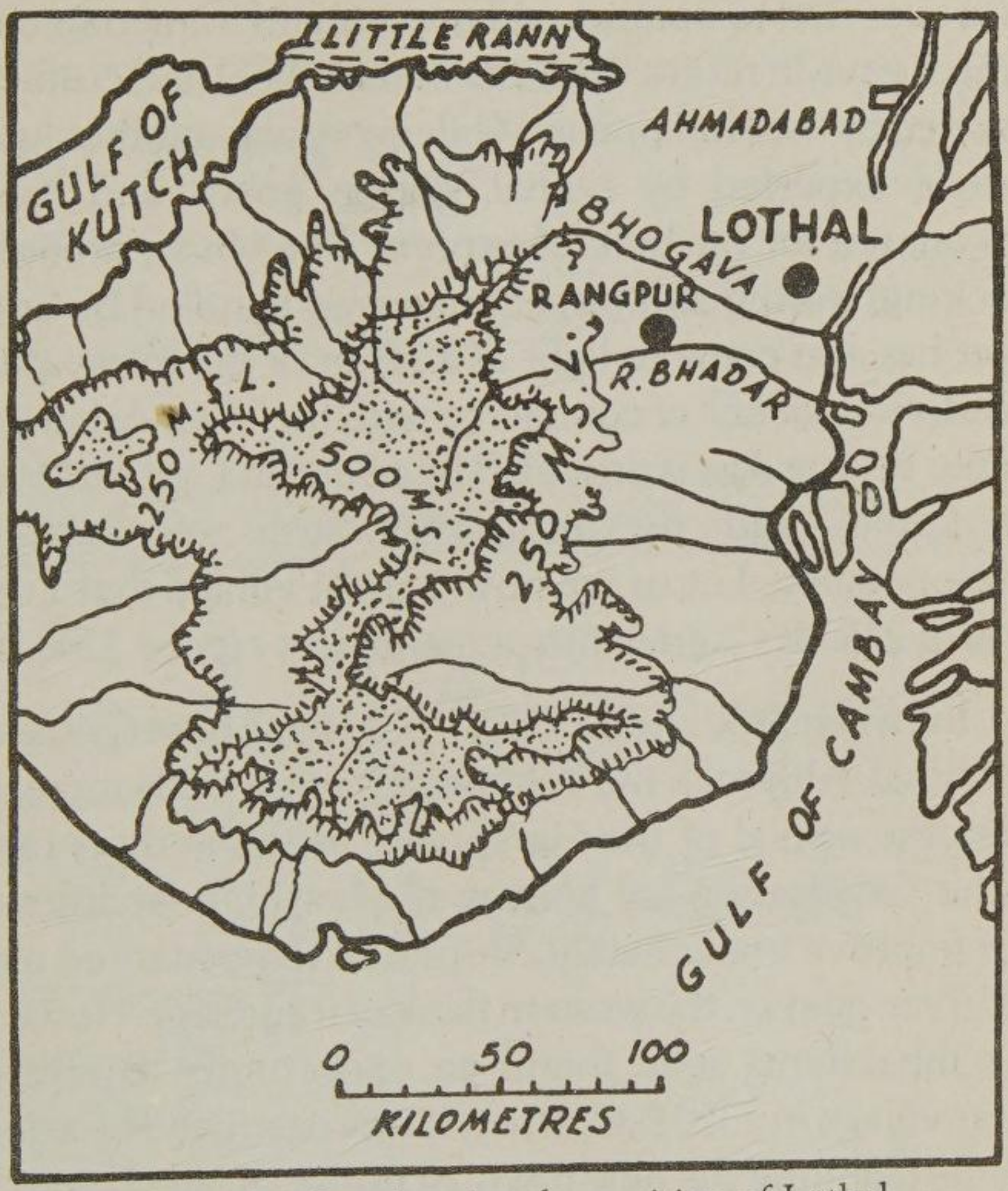

Fig. 1. Map showing the position of Lothal

wealthy merchants, artisans and other common people. Houses were built on 1 to 4 metre-high platforms of mud-bricks as a precaution against recurring floods in the river. The inhabitants were prosperous not only because of the abundance of agricultural, forest and marine products but also due to the fast-increasing overseas trade. Lothal developed several local industries to fulfil the needs of the Egyptian and Mesopotamian cities. For example semiprecious stones imported from the Narmada valley

were turned into beautiful beads in the factories at Lothal and exported to South Arabian ports and Sumerian cities, which gave in return the baser metals, wool and cosmetics needed by the Harappans. While ivory was another luxury article exported by Lothal, cotton goods and timber accounted for the bulk of exports. The whole process of packing, storing and inspecting cargo handled by Lothal port has also come to light as a result of the excavations. Positive evidence of commerce with the West Asian ports in the Bronze Age is provided by a Persian Gulf seal found at Lothal and the Indus-type seals recovered in Mesopotamia. Let us see how a small village that Lothal was in 2450 B.C. grew into a major port city by 2200 B.C.

Between 2450 and 2350 B.C. only small boats could call at Lothal. Although the volume of foreign trade increased after the arrival of the Harappans, as the authors of the Indus Civilization are known, the berthing facilities did not improve immediately. Ships had to be moored along the river-quay on the western flank of the village. However, the inhabitants soon found an opportunity to remodel their village in 2350 B.C. when it was destroyed by a flood. While planning the new town, or rather the new city, they added an artificial dock for berthing larger ships and in greater number than was hitherto possible. The engineers took care to build the dock away from the main stream but close to the city so that the ships could be safely berthed even during the storms. In the first instance a trapezoid basin, 214 x 36 metres, was excavated on the eastern margin of the city and enclosed with massive brick walls. The excavated earth was used for making bricks needed for constructing the wharf, warehouse and private dwelling. The designing of the structure reveals that all problems

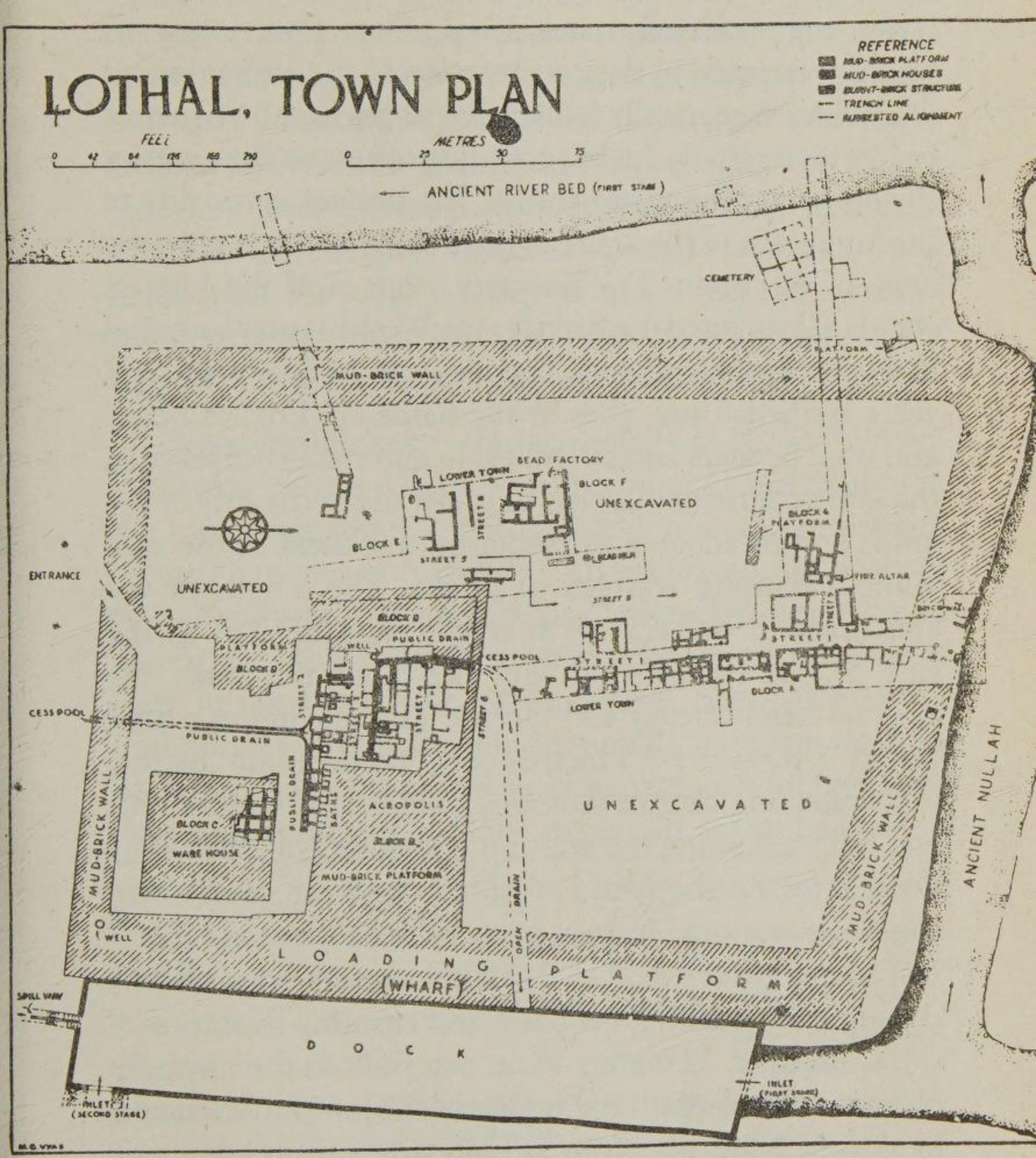

Fig.2. Lothal: Town Plan

relating to dockyard-engineering such as the rate of silting, the velocity of the current and the thrust of water in the basin were carefully considered. First class kiln-fired bricks were used in the construction of the embankment wall which is gradually reduced by stages from 1.78 metres to 1.04 metres in width by providing offsets on the exterior to counteract the water-thrust. The perfect verticality of the inner face of the walls enabled ships to reach upto the edge of the basin. The masonry work is of the highest standard known to the Bronze Age World. It may be noted here that the Harappans had developed four thousand years ago what now goes by the name of 'English bond' and used headers and stretchers in alternate courses or in the same course of masonry to break the verticality of the joints and to achieve the required thickness of the wall without causing wastage of bricks. The length of the embankment wall is 212.4 m. on the west, 209.3 m. on the east, 34.7 m. on the south and 36.4 m. on the north, the original height being 4.15 metres. The maximum extant height is however 3.3 metres only. To facilitate loading and unloading cargo a mud-brick wharf, 240 metres long, was built adjoining the western embankment wall of the dock at the northern end of which stood the quarters for the dock-workers. Judged even by modern standards it can be said that the Lothal dock was most scientifically designed for desilting the basin and ensuring floatation of ships. An inlet, 12 meters wide, was built in the northern embankment wall to enable large ships (of 20 to 25 metres length) to enter the basin at high tide and to have easy manouverability (Fig.2). At the opposite end a spill-way with 1.5 meter thick wall was built at right angles to the southern embankment wall to allow excess water to

escape. The easy flow of water at high tide ensured desilting of the basin. In low tide however the spill-way was closed by inserting a wooden shutter in the grooves in order to maintain the minimum level of water in the basin and thus facilitate floatation of ships. Apart from the structural evidence unearthed here, remains of logs of wood used as door-rests in the spill-way have also been found in the course of the excavation. Other interesting finds from the dock consist of three distinct types of perforated stone anchors. Postholes in the embankment suggest that some boats were secured to wooden posts.

Some significant technical details about the Lothal dock may be noted here. The minimum water-column in the basin was about 2 metres at low tide, the maximum being 3.5 metres at high tide. It is observed that boats of 60 to 75 tons capacity and 20 to 25 metres in length could enter the Lothal dock. The basin could accommodate at least 30 ships at a time. Mr. Lele has observed that the Lothal dockyard compares favourably with the modern dockyards of Bombay and Visakhapatnam which receive ocean-going steamers. Some details are given below:

Name of the port	Name of the dockyard	Length	Width	Depth	Remarks
1. Lothal	—	209.3 m (E) 224 m (w)	34.7 m (S) 36.4 m (N)	4.15 m at high tide; 2 m. over silt at low tide	Minimum depth
2. Bombay	(a) Mere Weather	152.4 m	19.96 m	6.71 m	-do-
	(b) Hughes (divisible in 2 compartments of varying length)	304.8 m	30.48 m	10.06 m	-do-
3. Visakhatpatnam		111.46 m	18.29 m	4.27 m	Below L.W.

The Lothal dock was in excellent condition for nearly 350 years (2350-2000 B.C.). After a major damage was caused to the structure by a great flood in 2000 B.C. It was repared quickly and berthing facilities were restored soon, but this was possible only after a great struggle. As a sequel to the flood the river silted up its mouth and took a sudden swing to the east of the town thus cutting off access to the ships from the Gulf of Cambay to the dock. The inhabitants were therefore forced to dig a new channel, 2 metre-deep and 2 km. long, to connect the dock with the sea through the river. They also provided a new inlet-gap, 6.5 metres wide, in the eastern embankment-wall for entry of ships, but this measure reduced manouverability and also kept away the larger boats owing to the shallowness of the new channel. The ocean-going ships had to be moored in the estuary about 2 kms. away from Lothal, the hauling of cargo being done by smaller boats. The flood not only damaged the dock, but also scared away some of the inhabitants of the city. After 2000 B.C. there was a marked decline in the material prosperity and urban discipline of the citizens. Trade too suffered 2 great setback. But the worse was yet to come. Another flood, nay a deluge, in 1900 B.C. swept out of existence Lothal and several other Harappan settlements in Kathiawar, and the Indus Valley. Even Harappa and Mohenjodaro seem to have suffered the same fate. At Lothal the dock was completely buried under a thick mantle of flood-debris. The panic-stricken citizens ran for safety to the villages in the interior. This natural calamity brought to an end a period of great prosperity of the Lothal port. With the decline in trade smaller and fewer ships called at Lothal after 1900 B.C. The town shrank in size and finally ceased to exist after

1600 B.C. but Lothal has continued to be the seat of the Sea Goddesses. Until 1957 the warehouse mound was considered to be sacred for the goodess, Vāṇuvatī Sikotarīmātā, and the devotees, mostly sailors, offered worship here.

(ii) Post-Harappa Period:

After the fall of Lothal in 1900 B.C. its place as a major port on the west coast was taken by Prabhāsa (Somnāth), a place considered holy right from the Mahābhārata times to the present day. When the Late Harappans occupied it in 1900 B.C. it was developed into an estuarine port to serve as a trade-emporium as well as refuelling station. Dwārakā, the identification of which is still in dispute, was another important port of the Mahābhārata period on the Kathiawar coast.

The Lothal dock could not have been a solitary instance of building artificial basins for berthing ships. There must have been at least a few more on the Gujarat-Makran and Kokan-Malabar coast wherefrom the Harappans received gemstones, timber, gold, steatite, etc. More than a dozen Harappan (2450-1900 B.C.) and post-Harappan (1900-1500 B.C.) ports have been discovered during the last thirteen years. Recently Sutkagen-dor and Sotka-Koh on the Pakistan Makran coast have been identified as Harappan ports. Further south Todio and Navinal served as fuelling stations on the Kutch coast, while Lakhabawal, Kindarkhera, Somnath, Kanjetar and Hathab on the Kathiawar coast and Mehgam, and Bhagatrav in the Narmada and Kim estuaries served as entrepots. To this list must be added Lakhapar, Pabhu Math and Surkotda situated on the northern border of

Kutch, as they indicate the ancient coastline when the Rann was an open sea.

The end of the Indus Empire caused great turmoil in the subcontinent. The Harappans who lived in the upper Indus basin sought shelter in the Ghaggar (Sarasvatī) and Chautang (Dṛiṣadvatī) valleys and still later in the Gangā-Yamunā doab. Those who lived in the lower reaches of the Indus came in several waves to settle down at the estuarine ports in Kutch, Kathiawar and south Gujarat. Thus came into existence at large number of small Late Harappan ports at the river mouths in the southern peninsulas. Amra, Lakhabawal, Prabhāsa (Somnāth), and Mehgam are some of Late Harappan ports excavated in recent years but all of them lack the grandeur of Lothal as a major port-town. For almost seven to eight centuries after the fall of the mature Harappan ports like Lothal, Bhagatrav, Sutkagen-dor and Sotka-koh, we find that India had lost its position as a major partner in overseas trade with the western countries. Until we come to the Mauryan period we have very little archaeological evidence to bridge the gap in the history of overseas trade between the end of the Indus cities and the rise of the Mauryan Empire. Some indirect reference to maritime activities is available in the epics and the *Purāṇas*. Our main source of information for the post-Harappan period is the *Mahābhārata* which recounts the exploits of its heroes in the distant past. Let us see to what extent we can rely on the information supplied by the *Mahābhārata*, the *Harivaṃśa* and other texts. According to *Harivaṃśa* the sage Sāndīpinī, and his disciples including Kṛṣṇa, the hero of the *Mahābhārata* are said to have gone in six boats from Bhṛgutīrtha, modern Broach, situated at the mouth of the

Narmadā river, to Prabhāsa (near Veraval) on the Kathiawar coast by sea. We know from the archaeological excavations at Prabhās that it was a Late Harappan port in 1900 B.C. and was in continuous occupations upto 300 A.D. According to K.M. Munshi, Prabhāsa was the abode of the early Aryans as well as the non-Aryans.

According to *Harivaṃśa* again, Punardatta, son of Muni Sandīpinī was kidnapped and taken away by Puṇyajana Rākṣasas who used to come to Prabhasa for trade. These Rākṣasa condemned by Aryans as barbarians and nicknamed as demons captured Kuśasthalī, which is identified with modern Dwaraka by some scholars. The Pañchajana ship in which Kṛṣṇa and his friend Uddhava entered stealthily at night sailed from Prabhasa. It was bound for Vaivasvatapurī which appears to be an Egyptian port where, according to legends, the Divine Mother ruled. Punardatta had been sold away by Puṇyajana Rākṣasas for a high price and was married to the princess of Vaivasvatapurī. The names of the persons working on the ship, namely, Bhikku, Kukkura, Radda, Kukku and Hullu bear close resemblance to those mentioned in the Sumerian texts relating to Dilmun trade. The *Harivaṃśa* says that Vaivasvatapuri, or the city of the Sun, was situated in Nāgaloka near Pātāla and was ruled by Nāgakanyās or snake-maidens. As the story goes, Kṛṣṇa rescued Punardatta after a fierce battle with the king of Vaivasvatapurī. According to Lenormant the Theban bas reliefs depict loading of Pharaoh's ships with booty after the conquest of Punt. The booty included among other things, animals, ivory and precious stones for which India was famous. Some scholars have suggested that Punt was the Nāgaloka of Mahābhārata times.

The archaeological evidence from Lothal shows that the Saurashtran ports had trade contacts with Egypt too in the arly part of the second millennium B.C. The Puṇyajana Rākṣasas might have belonged to Dilmun, where the Harappan merchants had established their colonies. Prof. Kramer identifies Dilmun with the Indus cities, while Prof. Bibby is inclined to identify it with Bahrain island. Whatever be the identification of Dilmun, one thing is certain: by 1700 B.C. Dilmun merchants had the monopoly of trade with India, and Kuśasthali (Dwārakā) situated at the tip of the Kathiawar peninsula seems to have come under their sway. Prabhāsa, Dwārakā and Sabarakaccha are three great ports mentioned in the *Mahābhārata*. About the high antiquity of Prabhāsa and its identication with Somnāth (near Veraval) there is no dispute. As regards the identification of Dwārakā of Mahābhārata fame with modern Dwarka convincing archaeological evidence is yet to be found. The excavations have yielded evidence of occupation from 200 B.C. onwards, but no finds of earlier date could be recovered here. It is said that the city of the Mahābhārata period was swallowed by the sea. To prove or disprove the traditional belief we will have to resort to underwater exploration near Dwārakā. There is another claimant for the honour of being identified as Kṛṣṇa's Dwārakā. It is situated near Kodinar and is known as Mūla Dwārakā (original Dwaraka). Its claim to high antiquity can be justified on the ground that a Late Harappan settlement has been discovered very near Kodinar, at the village of Kanjetar, which must have been an estuarine port in the protohistoric period. Next comes the question of the indentification of Sabarakaccha. The very name suggests that it was situated in the

Sabarmati estuary, and apparently there cannot be a better claimant than Lothal for this honour. But it must be noted that Lothal had ceased to be a port of any consequence by 1200 B.C., the generally proposed date of the Mahābhārata war. It is, however, true that Sabarakaccha too does not loom large as a port in the Mahābhārata period. Another port often associated with Kṛṣṇa and his friend Sudāmā is Krindarkhera traditionally known as Sudāmāpurī. It is situated on the southwest coast of Saurashtra. The earliest occupation of Kindarkhera goes back to the 1900-1800 B.C. period.

Bhṛgutīrtha or Bhṛgu-Kaccha, an important port mentioned in the *Mahābhārata* is identified with modern Broach. It was no doubt a great trade emporium and was known to the Greeks as Barygaza, but the excavations conducted by K.V. Soundara Rajan do not establish its claim for high antiquity. Perhaps the port of the Mahābhārata period lies elsewhere buried under a thick layer of silt. Mehgam, situated very near the sea, has a better claim for being identified as Bhṛgukaccha since archaeological remains datable to 1900-1600 B.C. have been found at the ancient site. It is not unlikely that Bhrgutirtha was originally situated at Mehgām, and was destroyed by one of the later floods in the Narmadā forcing the inhabitants to build a new township near modern Broach, which continued to be called as Bhṛgukaccha. The first occupation of Broach cannot be dated earlier than 600 B.C. according to the ceramic evidence from the excavations. It would be worthwhile excavating both Mehgam and Broach on a larger scale than has been possible so far to find out traces of a dock-yeard, if any.

Further south of Broach is a port presently known as Bhagatrav. It was established by the Harappan merchants in *circa* 2000 B.C. to collect gemstones quarried in the agate-bearing hills of Rājpipla. It continued to be an important outlet for the mineral and forest products of the Narmada-Tapti valleys until its functions were taken over by Mehgam in the north. Telod is another Late Harappan port situated in the Narmada estuary.

We are not certain whether Suppara, the modern Sopārā and Colliena (Kaliena) or Kalyān both situated near Bombay served as ports in the Late Harappa period (1900-1600 B.C.) or as for that matter, any time before the 6th cent. B.C. Gomantakapura or Gomantapura or modern Goa has been referred to in the *Mahābhārata*. A rapid survey of Goa area undertaken by the author in October-November, 1968 yielded ceramic wares of the Sātavāhana period at Chandour, the ancient Candrapura. According to *Harivaṃśa* Kṛṣṇa is credited with the discovery of the technique of smelting iron during his stay at Gomantakapura, but the tribal chiefs with whom he stayed produced weapons made of copper only. Archaeological explorations in Belgaum district have indicated that a chalcolithic culture with possible Harappan (of a very late date) affinities datable to 1500 B.C. flourished in this region. The copper-using fold seem to have been succeeded by the early iron-users of the Megalithic culture who built a unique type of graves known as 'passage graves' for burying the dead. All these evidence go to suggest that Goa had a longer history than is indicated by the evidence so far collected Goa must have been an important outlet for the mineral products of the Deccan plateau and the forest products of the Western Ghats.

The Bible itself mentions trade with Ophir or Sophir, i.e., Sovira. Book I, Kings, says that ships of Solomon (1015 B.C.) brought from Ophir gold, precious stones, etc. The book of Ezekiel is said to refer to Indian products brought to Tyre. Ivory, ebony and precious stones were exported from Gujarat ports in those days too. Furthermore, in the Hebrew text of the Book of Kings and Chronicles of the *Old Testament* the words used for peacock and fragrant wood are *tuki* and *ahalotu* respectively. They are of Tamil origin suggesting trade between south India and Jerusalem through Ophir in 1000 B.C. Caldwell and T. Foulkes are of the opinion that spices carried into Egypt by the Midiantist merchants of *Genesis* (XXVII, 25.28 and by the sons of the Patriarch Jacob (Gen. XIII, II) had their starting place in the sea ports of the Deccan.

(iii) Pre-Buddhist Period:

As we step into the first millennium B.C. we come across more and more literary references to the maritime expeditions and sea-brone trade undertaken by merchant princes and Captains of ships. The earliest of the Buddhist texts which refers to the sea-voyages undertaken in the pre-Buddhist period is the *Bāveru Jātaka*. Although this Jātaka (story relating to the earlier births of the Buddha) is assigned to the 4th century B.C. the folk tales on which it is based have a much earlier origin, some of them going back to the 7th century B.C. The overseas trade with the western countries notably with Egypt, Punt, southeast Arabia and Bahrain emanated at first from Sovīrā (Sophir) and later on from Sopparaka and Bhrukaccha. In the days of King Solomon Indian exports to Babylon included almug trees, gold and peacock. However, at the present

state of our knowledge it is not possible to give any comprehensive list of the items of export.

EARLY HISTORICAL PERIOD

A. Mauryan Period

For an account of the overseas trade between India and other countries we have to rely mostly on the Jātaka stories. The facts mentioned therein are often corroborated by the writings of the Greek writers. The *Arthaśāstra* of Kauṭilya also furnishes valuable information on the administration of the navy and ports. Very recently the archaeological excavations at Kāveripaṭṭinam and Dharaṇīkoṭā on the east coast have added to our knowledge of the port-installations in the early Buddhist period. A brief mention of the maritime activities of the Indians as noted in the various texts is made below. A Buddhist text known as *Siṁhalāvadāna* mentions that Prince Vijaya and his seven hundred followers banished by Siṁhabāhu, king of Bengal set sail from the mouth of the Ganga and came to Ceylon on the day of the Nirvāṇa of the Buddha. This great event became a fit theme for some of the paintings at Ajanta. According to *Mahāvaṁsa* Prince Vijaya took for his wife a Pāṇḍyan Princess who travelled along with several officers of State and servants in a large ships which must have set sail from Kaveripoom patinam. Apparently, large ships carrying hundreds of men must have been in use as early as the sixth-fifth centuries B.C. Another important text referring to commerce by sea is the *Bāveru Jātaka*. Bāveru is said to refer to Babylon, but some scholars think that Bāveru should be identified with Bahrain. Be that as it may, archaeology has now supplied

sufficient evidence to prove that India traded with Babylon as well as the Bahrain islands from 2000 B.C. onwards perhaps upto the 5th cent. B.C. Some of the Jātakas mention that merchants from Vārāṇasī and Rājagṛha sailed down the Gangā and then went westwards to reach the ports on the seaboard of Sobira (Sophir) in the Gulf of Kutch and others to Bharukaccha. From Sobira and Bharukaccha goods used to be sent to Bāveru. The merchants going eastwards used to sail from Banaras or lower down at Champā. After moving down the Gangā, the ships would go to Siṃhaladvīpa (Ceylon) or to Suvarṇabhūmi (*Chryse Chresonesus*) which probably included Burma and other countries to the east of India.

Mauryan kings not only encouraged sea-trade but also streamlined the administration of the navy. The *Arthaśāstra* vividly describes the duties of the head of the naval department and the port-officers. The administrative aspect shall be dealt with later. Important port-installations belonging to this period have been found recently at Kāveripaṭṭinam on the east coast, and Udyāvara on the west coast. There must have been many more such ones on the seaboard of India during the Mauryan period as is evident from the literary references, but they are yet to be uncovered by the spade of the archaeologist. Herodotus (450 B.C.) and other Greek writers have also referred to a number of Indian products reaching the markets of Greece.

B. Āndhra-Sātavāhana Period

(i) Sources:

Overseas trade encouraged by the Mauryan Emperors received further impetus under the Āndhra-Sātavāhana

kings and the rulers of the Chola-Pāṇḍyan kingdoms. Before the days of King Augustus India traded chiefly with Egypt since the Egyptian Greeks were the principal carriers of Indian goods via Ophir and Punt. Yemen played an important role as an intermediary. The led Aśoka to establish contacts with Ptolemy Philadelphus, the founder of Alexandria. The Yavanas referred to in the Buddhist *Jātakas* and Aśokan inscriptions are none other than the Ionian Greeks. Later on, however, all foreigners including Graeco-Romans came to be known as Yavanas. In the days of Agatharcides of Alexndria (177 B.C.) Sabia (Yemen) was considered to be the centre of commerce between Asia and Europe. Its importance increased tremendously because of the monopoly of trade with India. A number of indigenous sources espcially the *Jātakas* such as the *Śaṅkha, Valahassa, Mahā-Ummagga, Supparaka, Mahājanaka, Samuddha Vaṇiya, Silanisamsa, Sussondi*, etc., furnish valuable information regarding sea-voyages, construction of ships and the dangers to which navigators and passengers were subjected. But the evidence is mostly indirect. For direct evidence we have to depend upon foreign writers notably Strabo, Arrain, Pliny, Ptolemy and the author of the *Periplus*. While the last-mentioned writer was himself a navigator and produced a guide book for navigators, others depended for their information mostly on the Indian and Greek merchants who came to Alexandria. Ptolemy has recorded much useful data about Indian sea-ports, inland routes and trading stations, but he did not have a correct idea of the geography of the country. Besides literary references we have also numismatic evidence, both Indian and foreign, which confirm that trade between India and the Roman Empire had increased

tremendously during the Ist-4th cent. A.D. The most important source of information concerning the seaports of India is the author of the *Periplus* who hailed from Alexandria. He navigated the Red-Sea, the Persian Gulf and the Makran and Coromandel coast. The *Periplus* mentions that ships from India went as far as Socotoro near the African coast and to Arabia and the Persian Gulf ports. In this connection the name *Sikotarīmātā* given to the sea Goddess in Gujarat may have a reference to the African island. There are temples dedicated to Sikotarīmātā at Kūḍa near Gogha on the Kathiawar coast, at Mithli near Cambay, and at Hajira near Surat. Hathab, the ancient *Hastabra* situated near Gogha was a port in the Late Harappan and Roman periods.

(ii) West Coast Ports:

According to the *Periplus* the great Kutch was an open sea and ships could go round the island, but the unwary sailors would get into trouble in the shallow water. Ptolemy's *Geography* mentions Monoglosson (Mongrol on the west Kathiawar coast) and Syrastra (Surat) on the south Gujarat coast. Besides these two, as said above Hathab near Gogha, identified as ancient Hastabra, was an important port on the Kathiawar coast. This ancient port is used even now by large country crafts bringing timber from Konkan-Malabar coast. The *Periplus* refers to Suppara (Sopāra) and Colliena or Kalliena (Kalyāṇa), both situated near Bombay, Semylla or Somulla (Cheul), Mandagor (Mandad) and Palaepatmae (Pal near Mahad south of Bombay). Among the ports on the west coast mentioned in the *Periplus*, Tyndis, Muziris (Cranganore) and Nelkynda (Nileshwar) are important, but the last

mentioned site appears to have been an inland trading centre near the Malabar coast. On the east coast Camara (Khaberis of Kaveripattinam) south of Madras, Maisalia (Mosulipatnam or Macchalipaṭṭinam) and Kainapara (Konarak) find mention by Ptolemy. To the above list must be added a few more discoveries as a result of the exploration of the west coast between Goa and Udipi (Mangalore district,. Mysore State) undertaken by the author in 1968 with a view to ascertain if the ancient ports mentioned by the Greek writers could be identified on the basis of archaeological evidence. Goa received our first attention. The ancient site in Goa Velha where the Pilar Ceremony stands marks the ancient capital of the later Kadambas (of Goa) and is datable on the basis of sculptures and pottery to the 11th cent. A.D. The Portuguese are said to have first landed here, attacked the capital and distroyed the temples etc. A few sculptures recovered during the excavation are housed in a museum in the Seminary.

Next our attention was drawn to Chandour in Salsete situated at a distance of 18 kms. from Madgaon. It was known as Chandrapura and finds mention in the copperplate grant of King Bhoja which is dated 4th cent. A.D. Remnants of a brick temple, a citadel with a mud fortification wall and several other structures were laid bare by late Henry Heras during the excavations conducted by him in the early thirties. But the present exploration has brought to light pottery assignable to the Sātavāhana period. Thus it is evident that Chandour was an important town in the beginning of the Christian era. Goa is often identified with Gomantapura mentioned in the *Mahābhārata*, but the exact location of the city of the epic period is yet to be ascertained.

To the south of Goa lies the ancient port of Tadari near Gokarṇa which must have been an important port-town trading in spices and timber. Exploration at the foot of the rockshelters around Gokarṇa especially at Rāmatīrtha yielded a few sherds of gritty red and grey wares. Further south Honavar yielded a fragmentary polished stone axe, both suggesting contact with the Neolithic folk. Honavar is situated at the mouth of the Sharavati river and serves as an important outlet for the forest and mineral products of the west coast. In view of the recent discovery of a neolithic settlement by A. Sundara at Shimoga in Mysore state where the river Sharavati takes it rise, it can be safely assumed that the Neolithic folk moved down the escarpment of the Western Ghats to the small rock-shelters around Gokarṇa perhaps bringing with them gold which they mined in the Shimoga-Dharwar region for export purposes. The Sharavati river is navigable from Honavar upto Gersoppa which was a flourishing commercial centre known for its spieces and timber. Situated as it is at foot of the thickly-forested hills it must have served as an important emporium of trade during the 10th-15th century period, if not earlier. Traces of a large township with neatly laid-out streets and remnants of large temples built by the wealthy Jain merchants are still visible here. Further interior is Banavāsī the great capital of the Kadambas. Known as Vaijayantī, it was one of the wealthiest cities of India in the time of Aśoka, when several Buddhist stūpas and Vihāras came to be built here. A thorough exploration and systematic excavation may bring to light a protohistoric settlement also. A preliminary survey by the writer has yielded ceramic wares datable to the 3rd cent. B.C. confirming the literary reference to

Banavāsī as a flourishing city in the time of Aśoka. A Sātavāhana lead coin found here clearly proves that the Sātavāhanas too had trade contacts with it.

The most important port discovered during the present survey of the west coast is the one at Udyāvara mentioned as *Odāra* in the *Oxhyrinchus papyrus*. It is a small village 6 kms. south of Udipi, wherefrom the greant saint Madhvācārya hailed. Even now country crafts from Gujarat ports call at Udyāvara for buying timber. The mound known as Baleragudda marks the citadel of this ancient port-city. The lower extending over more than 20 acres has yielded large quantities of black-and-red and black polished ware, both assignable to the 3rd cent. B.C., but the occurrence of a chert blade suggests a much earlier date than the black-and-red ware does. However, the citadel with its mud rampart pierced by gateways may not be earlier than the 3rd-4th cent. A.D., but it is interesting to find that Udyāvara was a well planned town in the early centuries of the Christian Era. The local gentry have collected from the mound small circular foils of gold which might have served as coins in ancient times. When fully examined they may throw valuable light on the commercial ties of Udyāvara with Rome.

We now pass on to the Malabar coast. The author of the *Periplus* and other Greek writers mention Muziris, which is identified with Cranganore on the Malabar coast. The site excavated has yielded ceramic and numismatic evidences thus confirming its occupation in the Ist-2nd cent. A.D., but a systematic excavation, than has been hitherto possible, may throw more light on its history in the pre-Christian era. Nelkynda (Nelcynda)

identified with Nileswhar is another port known to the Roman traders for spices and timber.

(iii) East Coast Ports:

So far as the east coast is concerned we have reliable literary evidence. The early Tamil works of the 1st century A.D. such as the *Paddinappālai* and *Chilappathikāram* have described at length the port establishments and the markets of Poompohar, i.e., Kāveri-poopattinam, the chief port of the Chola Kingdom on the east coast. Two other ports which are significant from the point of view of commerce during the first few centuries of the Christian era are Arikamedu near Pondicherry now identified as Pokduke or Poduca and Kainapara or Konarak in Orissa. While referring to the expansion of overseas trade in India we will have occasion to mention the part played by the kings of Kaliṅga (Orissa). South of Madras but slightly north of Kāraikal is an ancient port known as Nāgapattinam where a brick-built wharf existed in the 5th cent. A.D. In the course of the pile-driving operations near the present harbour some brick structures had come to notice but no systematic excavation was carried out subsequently. The famous Buddhist bronzes found at Nāgapattinam are also assignable to the 5th cent. A.D. Thus it is evident that at least during the early Chola period Nāgapattinam was a fairly busy port.

The most important port of the early Cholas is Kāveripattinam, also known as Puhar in Tamil literature and mentioned as Kaberi by the author of the *Periplus*. This ancient port-city has been destroyed beyond recognition partly by agricultural operations and partly due to encroachment by sea. The Tamil works

Maṇimekhalai and *Paddinappali* assignable to 2nd-5th cent. A.D. refer to the destruction of the city as a result of the curse of Kannagi, the celebrated heroine of the epic *Maṇimekhalai*. The site was surveyed carefully by the author and trial pits were sunk in selected areas during the years 1963 and 1964. As a result of these operations a large water-reservoir of the early historical period, a Buddhist vihāra (monastery) assignable to the 4th-5th century A.D. and a brick-built jetty detable to 300 B.C. have come to light. At the zenith of its prosperity this port-city extended over an area of 9 square kms. and could boast of a number of wharfs and warehouses built to handle cargo brought from distant lands. The Tamil works refer to the colony of Roman merchants established at Kāveripattinam. The low-lying area in a locality known as Kilaiyur which indicated a silted-up channel or creek flanked by sand dunes was excavated. The brick structures laid bare here conform to the description of whars mentioned in the *Paddinappālai*, which says that several brick-plantforms were built near the habour for haulage of cargo. Fortunately, one such platform measuring 18.28 x 7.62 metres with a centrally-built channel for excess water to escape at high tide has been laid bare. The channel and brick platform must have been covered with wooden planks supported by thick wooden posts embedded along the inner edges of the channel. As many as eight postholes and stumps of wooden posts noticed along the channel throw some light on the nature of platforms built for loading and unloading cargo. The date assigned to the wooden posts by Carbon-14 method is 300 B.C. Obviously Kāveripattinam must have been a flourishing port centuries before the author of the *Periplus* visited the port. According

to the *Paddinappalai* the Kaveri was a broad and deep stream into which large ships, laden with cargo used to enter from the sea without slackening of the sails. The town (Puhar) 'Kāvirī-paddinam', as was then known stood on the northern bank of the river, a fact confirmed by archaeological excavations. It was divided into two parts. One of them, known as Maruvar-Pakkam was the harbour area where cargo used to be stored in warehouses and on brick platforms. One of the platforms laid bare in the excavations answers to the description in Tamil works. The discovery of square copper coins bearing a tiger motif on one side reminds us of the fact that goods landing at Kāveripattinam used to be stamped with seals bearing the royal emblem of the Chola Kings, namely the tiger.

Arikamedu or Podovake Emporium of Greek writers was one of the treaty ports where permanent lodges of Roman traders were settled under formal agreements with the rulers. It is now a small village near Pondicherry situated on the bank of the river Ariyankuppam which is landlocked and forms a lagoon. The ancient site was first excavated by French archaeologists in 1941. Two notable features of the 1945 excavation by the Wheeler are the discovery on Indian soil of Roman pottery definitely datable to the second quarter of the first century A.D. and the identification of the warehouse and dye-vats at Pondicherry. The 'warehouse', '135 meters long and 8 metres wide, laid bare in the northern sector of the port is oblong in plan and opens into the river. The side chamber appears to be a later addition and the partition wall itself may be earlier in date than the construction of the warehouse since it underlines the floor level of the latter structure. In view of the fact that the basin formed by the

brick walls opens into the river the structure could have served as a dock too. As the excavator has designated it as warehouse, we may take it as such, since warehouses were common in those days. It is interesting to note that the main walls of the warehouse were built on rough foundations of bricks sun on rubble soling. The occurrence of abundant pottery and cuttimber below the sea level may indicate remains of ships and their cargo. Pondicherry, like many other Indian ports imported Roman wine in amphorase some of which have been found in the excavation. Roman glass and stamped pottery emanating from some well-known ceramic centres in Italy are among other finds from Pondicherry. In the southern sector of the town industrial establishments were noticed, the chief among them being brick-built tanks used as cisterns or vats for dyeing muslim which was an important item of export from southern India. There were regular drains to permit constant flow of water into and out of the vats. In brief it can be said that archaeology has confirmed literary evidence and established that Poduca of *Periplus* was a busy emporium of trade on the east coast of India.

Further north of Kāveripattinam two important ports have been mentioned by Ptolemy namely Masalia (Masulipatam) and Kainapara (Konarak) but we have little archaeological evidence to further our knowledge of the port-establishments at these places. On the other hand, the existence of a river-port in the early centuries of the Christian era has been brought to light by late Venkataramiah and Shri Raghavachari at the Buddhist site known as Dhānyakaṭaka or Dharaṇīkoṭā near Amarāvatī in the Guntur district of Andhra Pradesh. An embankment-cum-wharf abutting a navigational channel

was built here in phase I of the occupation. In phase II a huge wharf was raised upon wooden posts which are indicated by rows of postholes encountered in the excavation. In phase III a brick wharf was built along the inner side of the channel and the embankment wall was also raised in height. During this phase the navigational channel was repaired and the embankment walls were reinforced in subsequent phases. The excavation at Dharaṇīkoṭā has yielded Rouletted Ware and Sātavāhana coins. The first phase of occupation when the channel was cut is dated to 200 B.C. by the excavator and the wharf built in phase II is said to be slightly later in date. The evidence from Dharaṇīkoṭā proves beyond doubt that even at minor river-ports wharfs of timber and brick were built to facilitate haulage of goods as early as the 2nd cent. B.C. We have been earlier at Lothal that the practice of constructing wharfs and dockyards goes back to 2350 B.C. It follows, therefore, that at almost all the sea-ports mentioned by the author of the *Periplus* and by Ptolemy some kind of a dockyard for anchoring ships and wharfs for haulage of goods must have existed.

Tāmlūk or Tāmralipti referred to as Tāmalipta in the Buddhist *Jātakas* was a great emporium in the first few centuries of the Christian era. It was an estuarine port, and the literary reference to its overseas trade with the Roman world has been confirmed by the archaeological finds from the excavations conducted by M.N. Deshpande in 1954-55. Cast copper coins and terracotta figures characteristic of śunga art found in the early levels help to assign Period II to the third century B.C. Still earlier, however, the Neolithic folk had occupied the site. It is in Period III that pottery and other objects of foreign origin

attributable to overseas trade have been found. Rouletted Ware was one of the ceramic wares which had their origin in the Roman world. Among the signficant structural remains of the 2nd-3rd cent. A.D. laid bare at Tāmlūk mention may be made of a brick-built tank which indicates days of prosperity.

C. Gupta Period and Later

The Gupta Emperors also encouraged inland and overseas trade, but unfortunately we have no direct literary or inscriptional evidence from India to gain an idea of the size of ships, the nature of merchant-guilds engaged in sea trade, the commodities traded in and the countries where Indian merchants had established their colonies. For this information we have to depend on foreign sources mostly. In the 5th century A.D. Hamza of Isahan writers (Yule: *Cathay and the Way Thither I, xxviii*) that Indian ships used to be moored at Hīra near Kufa on the Euphrates river, the major role in sea trade being played by the merchants from Sind and Gujarat. Mention has already been made of the fact that it is the seafaring merchants of Gujarat who colonized Java. Cosmas mentions in his *Christian Topography*, (I,c, xxviii) that in the first quarter of the 6th century A.D. Debal (Sind) and Orhat (Sorata, i.e., Veraval) took active part in trading with Ceylon. The pressure of the White Hūṇas drove the Jats to Bahrain island from Sind and Kutch. Thus the Persian Gulf island came to be colonized once again by the Indians. Hiuen Tsang (630 A.D.) who visited Valabhīpura, a renowned Buddhist centre in Saurashtra, observes that the people of the peninsula were a great commercial people and earned their livelihood by engaging

themselves in sea trade. According to Beal (*The Buddhist Records* II, p. 269) the Hindu merchants had settled down in the major towns of Persia and carried on trade in the beginning of the 7th century A.D. without fear of being persecuted. However, the frequent attacks of the Mohammadans against Gujarat and Sind in the 7th-8th centuries forced some of the merchants from Gujarat to migrate to Java and Cambodia, where they established large colonies. Hindu kingdoms came to be established here. Throughout history except in recent years Cambodia and Java imported the costly silk sarees from South India and Gujarat. The famous Pāṭana Paṭolas (sarees) produced (in tie-and-die method) by the silk-weavers of Gujarat who are referred to in the Mandasor stone inscription of the Gupta King were exported to Cambodia as late as 1935 A.D. The silk itself came from Mysore wherefrom some of the silk-weavers had migrated to Gujarat. The Gurjjars of the Chāvḍa (Chāpotkaṭa) class who rose to power in Aṇahilvādā Pāṭana put down the piracy of the Jats along the Kathiawar coast in the 8th cent. A.D. Let us see how maritime trade developed in South India during the Chola rule.

After the decline of trade with Rome the Chālukyan and Chola Kings encouraged sea trade with the eastern countries espcially Burma (Savarṇabhūmi), Sumatra, Java, Borneo and the island of Bali. I-Tsing, the Chinese traveller who visited India in 673 A.D., says that at all the busy ports of the east coast from Burma to China and those in Malayan arhipelago, the colonies of Indian merchants could be seen. Sanskrit learning and Hindu including Buddhist religous practices flourished in Java and at

Mahasin in Borneo. The islands of Bali and Bhogapara had been Indianized.

The ports of Burma, Java and China served not only as fuelling stations but also as centres of trade and learning. Buddhist monks from China came to India by sea, the chief among them being Tao-lin who visited Tāmlūk (Tamralipti) in Bengal. He came by way of Java and Nicobar islands. Among the Indian Buddhist monks who went to China mention may be made of Vajrabodhi who became the founder of estoeric Buddhism in China. Bodhidharma of south India went to Japan and met Prince Shotoku (573-621 A.D.). Bodhisena who had gone to China to see Mañjuśrī visited Japan in 736 A.D. These exchanges of Buddhist evangelists between China and Japan on the one hand and India on the other was possible because of establishment of Indian trading stations on the sea coast of Burma, Malaya, China and Japan and the Hindu kingdoms in Java, Bali, etc. We need not go into the details of the remarkable outburst of naval activity under the Vijayanagara and Maratha powers on the west coast and of the later Chola Kings on the east coast as it falls outside the scope of this paper.

SHIP-BUILDING IN ANCIENT INDIA

A. Material

Wood is an important requirement for boat-building and a few good varieties of it are available in India. Teak was used for this purpose at Lothal in 2200 B.C. as can be judged from the charred wood specimens found in the dockyard. According to Ramesh Rao and others teak

grew in abundance in the Panchmahals district of Gujarat in the protohistoric period. It is not known whether acacia and sisoo available in Gujarat were also used for boat-building at Lothal. Perhaps other varieties were imported from the west coast ports of south India. In this connection it may be noted that according to Pāṇini (5th cent. B.C.) *Śiṃśapā* (*Delbergia sisoo*), *Ámra* (*Mangifera indica*), *Śāmali* (*Bombax malabaricum*) and Khadirā (*Acacia catechu*) were used for ship-building. Strabo (60 B.C.-19 A.D. says that Alexander constructed a fleet from pine, cedar and other trees cut from the forests in the territory of King Poros. India appears to have exported timber suitable for shipbuilding to Mesopotamia in the time of King Nebuchadnezzar (604-562 B.C.), for, the teak wood found in his palace is said to have come from India. According to the author of the *Periplus* Barygaza exported teakwood and ebony to the ports of Apologues (Obollah) and Ommana (Oman) on the south Arabian coast. In the early historical period most of the teak needed for building ships at the Indian and Persian Gulf ports must have come from Honāvar, Kārwār, Gokarṇa (Tadarī), Malpe, Udyāvara, Muziris (Cranganore) and Nelcynda (Nileśwara). Even now the Machwas from Gujarat carry timber from Konkan and Malabar ports to Ratnagiri, Sopāra, Bulsār, Broach, Verāval, Porbandar, Māndvī and Anjār (Kutch) in the country crafts thus covering a distance of nearly 2500 kilometres.

B. Construction of Ships

(i) Hull and Keel :

Some idea of the method of constructing ships can be had from the representation of ships in the paintings at

Ajanta and the sculptural representations at Barhut, Sanchi and Borobudur. The hull of the seaworthy vessels consisted of a keel and ribs covered by planks. From the vessels painted at Ajanta, the tennon-and-groove system of joining planks horizontally (edge to edge) becomes apparent (Fig. 3). The shipwrights of ancient India had evolved a unique method of joining the planks of the hull by stitching them together, a technique developed from the inflated floats (skin boats). In the beginning planks of soft wood such as *Śālmali* (*Bombax malabaricum*) must have been stitched easily with palm firbre and later on this method was transferred to hard wood like teak, devadāru, etc. Holes were bored in the wooden planks with drills. The use of twisted drill was known to the shipwrights of Lothal as early as 2200 B.C. In fact, they were the first to invent and use it for boring holes in hard wood and metal. This unique tool from Lothal is made of bronze. The use of perforated stone anchors and the introduction of the twisted drill at Lothal clearly indicate that it was a ship-building centre. At present a red hot iron rod is used for boring holes in wooden planks and a cord of jute or coir dipped in cashew-nut pitch for serving. The rope-joints were preferred to the use of iron nail for joining planks even in the time of the author of *Yukti-kalpataru*, a work of the 11th cent. A.D., for according to him, iron attracted lodestone and resulted in the sinking of the ship. A more convincing reason is that sewn hulls were more resilient and did not easily break up if they ran on rocks. Although iron was widely used in India by 400 B.C. and the technology had been developed as early as 700 B.C., it was more economical to adopt the sewing technique since the raw material needed was easily available. Another

technique of joining planks known to the Indian shipwrights is the fish-joinery, wherein wedge-shaped pieces of wood are inserted in the joints of the planks as can be seen in the sculptural representation of a boat carrying three ascetics on the Eastern Gateway of Stupa No. 1 at Sanchi. The advantage in fish-joinery (Fig. 4) is that wood expands when soaked in water and the planks are held together firmly by reducing the width of the joints. In this technique the use of iron nails is avoided and there is no danger of corrosion from the rusting of the metal. Leakage arising out of improper securing of joints in the hull-planks were stopped by caulking the seams. The *Tilakamañjari* says that the chief sailor used to caulk even small holes before the ship set sail. Clay, grass, or metallic pieces were used for caulking. The *Ācārāṅga Sūtra* refers to caulking with cloth, clay, etc. According to the Tibetan Version of the *Avadānaśataka* there was a class of crew for stopping leakages. The *Arthaśāstra* also refers to sailors whose duty it was to take out water in case of leakage.

(ii) Mast:

The number and height of masts depended upon the size of the sea-going vessel. It was erected on the keeled base to carry the sails, ropes, and braces. There is an interesting reference to masts in the *Milindapañha*. At times the mast was so high that a ladder was used for climbing it. The *Śaṅkha Jātaka* mentions that Śaṅkha climbed up the mast and jumped into the sea when the ship was about to be wrecked. In the Borobudur sculpture, a ladder for climbing up the mast is also shown. On top of the mast there was provision for the "look-out man" to sit.

The number of masts varied from 1 to 3 and sometimes even more. If the ship had only one mast, it was fixed in the centre, but the two-masted ships represented on Andhra coins have the masts so spaced as to keep the balance of the vessel. Three-masted ships are seen in the Ajanta murals (Fig. 5), while multi-masted ships are noticeable in the Borobudur sculptures (Fig. 6), where the tops of the inclined masts are found to meet in groups.

(iii) Sail:

We do not know what type of sail was used in the Harappan times. If the sail depicted in the ship engraved on a potsherd from Dhulia, a Late Harappan site, is any indication it must be admitted that the Harappan sails were partly rectangular. Lateen sails do not appear to have been known in the Harappan times and perhaps later too. The occurrence of square and rectangular sails in the Ajanta paintings (5th-6th cent. A.D.) suggests that the voyages were timed according to the seasonal movements of the wind. It is only in the early medieval period that lateen sails were introduced to beat into the wind.

In the Barhut sculptures and on Andhra coins the steering oars of the ships are depicted. They must have served as rudder in ancient times. The rudder itself is a medieval invention. *Yukti-kalpataru* has repeatedly mentioned this invention.

(iv) Deck and Cabin:

All sea-going vessels must have had a deck, which acts as a roof to the holds and also prevents water from entering the ship in the event of its rolling in the sea. A poop-deck is noticeable in the three-masted ship painted

in the Ajanta caves (Fig. 5). One can see basket-work fencing along the gun wale serving as an enclosure to the deck on the ship represented at Borobudur.

Cabin was a necessity to provide shelter to the crew against rain and sun. As such even the Harappan ships had cabins as indicated by the seal-engraving and terracotta amulet from Mohenjodaro. In the sculptural representation of a boat on the Sanchi Stūpa and in the Ajanta painting a cabin can be made out. It is also depicted in a boat engraved on the potsherd from Dhulia.

(v) Types of Boats:

Three types of boats are recognisable in the terracotta models from Lothal. One of them is flat-based as in the case of river rafts, while the other two types have high keels. Both have a high-pointed stem and stern to facilitate turning of the vessel by steering oars. There is, however, no evidence of outriggers. The Lothal model suggests that the ships used to be broad and strong and they were safe even without outriggers. The prow was often decorated with fanciful animal figures as in the case of the Ajanta and Sanchi boats (Fig. 7). The *Rājavalliya* and *Yuktikalpataru* mention various types and sizes of boats. The author of the *Periplus*, Ptolemy and other foreign writers have named a few; but unfortunately no actual remains of boats of the early historical period have been found. It is however evident from the Ajanta paintings (*Mahājanaka* and *Śaṅkha Jātakas*, and the *Siṁhalāvadāna*) that a large number of persons and even elephants could be carried in the multi-oared ships. The Royal navy was well-equipped with such ships in those days.

TRADE WINDS

Long before Hippalus discovered the monsoon-winds, Indian sailors possessed a sound knowledge of the periodicity and regularity of the winds in the Indian Ocean without which the Harappan vessels could not have made regular voyages to the East African coast (Socotoro), Egypt, the Bahrain islands and the Persian Gulf as suggested by the exchange of luxury articles and daily necessities. Besides a knowledge of the usefulness of monsoon winds for navigation purposes, the Indian sailors had developed astronomy into a great science and depended on the stars for direction.

EXTENT AND ORGANIZATION OF OVERSEAS TRADE

The Harappans, the Dilmun merchants and later on the Phoenicians were actively engaged in sea-borne trade between Egypt, the Persian Gulf and Sumer on the one hand and India on the other during the third and second millennia B.C. They carried considerable quantities of cargo including timber, cotton, wood, gemstones, precious and base metals, spices and cosmetics, and even birds and animals. How extensive was overseas trade in the protohistoric period can be judged from the fact that ivory rods produced at Lothal reached as far as Ras Shamra on the north Syrian coast at the close of the third millennium B.C. Besides seals the Indus cities have yielded other evidences of contact with Mesopotamia. At Mohenjodaro and Lothal circular beads of gold with axial tubes, similar to those occurring in the Royal Cemetery at Ur have been

found. The compartmented stone vases noticed at Mohenjodaro must have had their origin in the Euphrates-Tigris Valley. The bull-amulet of copper recovered from Lothal is reminiscent of similar amulets in stone and silver from Ur and Susa. It is not necessary here to make a long list of the knicknacks exchanged between the Indus and Mesopotamian cities. But it must be noted that unless sea-borne trade was very well organized exchange of goods on so vast a scale in the protohistoric and early historical periods would not have been possible. It would, therefore, be interesting to know how commerce was organized in the hoary past.

Recent discoveries by American expeditions in the Kirman region of southern Iran have brought to light a large number of circular Persian Gulf seals, stealite compartmented vessels, beads, etc., at Tépé Yahaya. It is possible that the site served as an intermediary station for import-export trade.

The wealthy merchants of Lothal seem to have organized themselves into partnerships, a fact which has been brought to light as a result of the discovery of terracotta sealings bearing impressions of seals of more than one merchant-owner. It is not unlikely that merchant-guilds were also established in the Indus cities by 2000 B.C. If the analogy of Sumerian trade is extended to Indus trade it must be concluded that the merchants ashore advanced money to the captains of ships for buying goods, but shared no risk involved in sea-voyages. They, however, demanded a share of the profits. Rules of conduct were firmly established in Sumer and, by inference, in the Indus valley and Kathiawar too. A.L. Oppenheim *[Journal of the*

American Oriental Society 74, (1954) p. 10] quotes from the clay tablets from Ur to prove that high moral standards were maintained in conducting trade. The reference here is to the letters addressed to a travelling merchant by name. Enasir who imported copper according to the weight-standard of Telmun and also ingots termed *guburam* each weighing upto 4 talents. He complains to Enasir of supplying ingots of sub-standard quality and weight. The author of the tablet says that the merchant promised 'good' *guburam*, but bad ones were shown to his messenger with the added insult of saying 'take it or leave it'. The tablet concludes with a warning from the author to Enasir to 'behave like a gentleman'. This is how the merchant was chided. The trade in copper was very extensive, as can be inferred from the fact that a ship-wreck salvaged off Cape Galedonia near the Turkish coast has yielded ingots of copper similar to those found at Lothal, Susa and Cyprus. The Galedonian ingots are assigned to the second millennium B.C. As we shall presently see this trade in copper passed through Dilmun which T.G. Bibby identifies with the Bahrain islands whereas S.N. Kramer is inclined to identify it with the land of the Indus Civilization. In the latter case Lothal was the most important emporium of Indus sea trade.

Warehouses

The establishment of warehouses at sea ports appears to have played an important role in safeguarding cargo, ensuring the quality of goods and establishing the identity of the consigners and the consignees besides facilitating the collection of customs duties. Lothal could boast of the largest warehouse of the Bronze Age so far known (Fig. 8).

It was built on a 4 metre-high podium of mud-bricks in close proximity to the dockyard and a ramp was provided for transporting goods in vehicles from the wharf to the warehouse. To ensure that the cargo stored on the brick platforms built within the timber structure did not deteriorate, proper air-vents were provided. Intersecting passages for free movement of labour engaged in handling cargo are also seen in the warehouse. The bales were packed in mattings and occasionally in woven cloth of cotton or flax if the contents were very precious. The outgoing packages were then sealed by the port-authorities as well as the consignors to establish the source and geniuneness of the goods exported. Similarly, the incoming goods were examined and delivered to the consignees. At Kāveripattinam the goods used to be sealed in token of payment of custom duties before delivering them to the consignee. One of the jar-lids found at Lothal bears impressions of seals carrying asvastika motif similar to the one on the seals from Brak and Susa. Apparently the said jar must have come from Mesopotamia duly sealed.

Another aspect of foreign trade brought to light at Lothal should be mentioned here. Between 2000 and 1900 B.C. after the effective control of the city-ruler over industry and trade was relaxed the wealthy merchants or merchant-guilds appear to have taken control of factories and managed them almost on the lines of modern factories. They employed craftsmen, supplied them with raw materials, paid wages in kind and exported the finished products. This becomes evident from the factories of bead-makers and coppersmiths encountered at Lothal where a large number of workers worked and lived in the premises of the factories.

PAYMENT OF TAXES

From the Sumerian clay tablets we know that the sailors who came back safely to their city had to pay a part of the goods as tax of the temple authorities. On this analogy we may say that the goods brought into Lothal too must have been taxed by the ruler. The *Arthaśāstra* and early Tamil works clearly give the amount of tax levied on imports. The Buddhist *Jātakas* too throw some light on this aspect. The *Arthaśāstra* gives us further valuable information regarding the administration of ports, the assistance rendered to the navigators in case of ship-wrecks and protection afforded to them against pirates.

MECHANISM OF LONG-DISTANCE TRADE

From the earliest times to the present day the merchants have been adopting various methods to identify the source of the goods bought and sold by them and to insure their quality and quantity. The reputation of the individual or the firm counts much in long-distance trade. The buyer has to depend on the credentials of the seller, who in turn to make sure that goods are not tampered with in transit. For this purpose the containers are sealed by the consignor. The Indus Civilization also introduced this system. Their seals seem to mention the names of the consignor besides a motif, animal or geometric. The types of seals used in some parts of the world differed from those of the others. Whereas the Indus merchants used square stamp seals of stone bearing their pictographic writing and animal motif, the Mesopotamians used cylinder stone seals with a cuneiform writing and animal or plant motifs. The Bahrain

merchants preferred circular stamp seals of steatitie with animal motif. Sometimes Indus script was also engraved on them. As a result of exchange of goods Indus seals have been found at Ur, Kish, Asmar and Umma, while three cylinder seals of Mesopotamian workmanship occur at Mohenjodaro. A dozen circular stamps with Indus motif and script found in the Euphrates-Tigris Valley were till recently assumed to have originated in the Indus Valley. But the discovery of a large number of circular seals Bahrain has given a clue to their origin and authorship. It is the Indus merchants living in Bahrain who carried the circular seals to Mesopotamia. A positive proof of trade between India and Bahrain is provided by a circular seal found at Lothal. It carries motifs common to the 'Persian Gulf Seals'. A double-headed dragon flanked by jumping gezelles is noticeable on one side, while on the other side is a low circular boss with two holes across it. Another significant trade-mechanism of Bronze Age is the stone weight. Here again each civilization had its own distinct type and standard of weight. While the Harappans used a tetrahedron, the Egyptians and Sumerians used duckshaped and barrel type weights.

Cubical stone weights of Indus Civilization have been reported from Qula-at-al-Bahrain and Ras-al-Qala too. Obviously the Indus-merchants must have used them. It is interesting to note that the Lothal merchants used two standards of weights, one conforming to the standard prescribed in the Indus valley and the other with a unit conforming to the Heavy Assyrian shekel in vogue at Susa. The introduction of the Assyrian system was necessitated by the extensive sea trade Lothal had developed.

The use of seals and weight continued in the Buddhist period and several terracotta sealings belonging to merchant-guilds have been reported from early historical sites the chief among them being Jhusi near Allahabad.

ADMINISTRATION OF PORTS

The development of national shipping under the Mauryas was possible due to the creation of a Board of Admiralty under the War Office Chandragupta Maurya. The *Arthaśāstra* gives details of the working of this Board under the *Nāvādhyakṣa*, i.e., Superintendent of Ships, whose duty it was to collect all the dues at the port. Besides customary tax levied on merchants, the villages on sea-shores had to pay a fixed amount of tax. It was also the duty of the Superintendent to give all possible help whenever a storm-beaten ship arrived at the port. He could reduce tax or exempt the ship-owner or merchant from payment of customs in the case of cargo spoilt by water. State vessels built by craftsmen engaged by the Government were given on hire to private individuals for pearl-fishery. Damage or loss due to the defect in such vessels was made good by the Superintendent. He was also expected to enforce regulations laid down by the State in the interest of trade, the crew and the passengers. He could punish those violating harbour regulations and arrest persons trying to smuggle goods and escape punishment by law courts.

Certain facilities such as pilot-service existing at Indian ports have been mentioned by the author of the *Periplus*. At Barygaza King's men used to go up to the coast of Syrastrene and pilot vessels to avoid dangers from

shoals, etc. They enchored them to fixed stations Men on vigilance duty are mentioned in the Kanheri inscriptions. Perhaps they guarded sea-routes and piloted vessels safely into the ports. From the above details it becomes evident that the Superintendent of the Port had multifarious duties to perform in the Mauryan period an later too. Considering the position of vantage occupied by the Ruler's mansioin at Lothal built overlooking the dock it can be inferred that he acted as a port officer and supervised the transactions of the warehouse too.

MERCHANDISE

The Indus cities, especially Lothal, exported luxury goods, such as gemstones, beads an ivory articles. To this list must be added gamesmen, bangles and inlays made of shell which is available on the Kathiawar coast and the Palk Straits. India also exported cotton and cotton goods for which the Indus valley (Sind), the Deccan and Kathiawar (Bhal where Lothal situated) were famous. Timber of good quality available in the forests of Malabar and Konka found their way to Mesopotamia. Beads of precious stones in the manufacture of which Lothal had specialized were in great demand. The Egyptian tombs, the Royal Cemetery at Ur and the temples and private houses at Brak, Kish, Lagash, Susa and Asmar have all yielded stone beads traceable to the Indus cities. Kidney-or-heart-shaped inlays of ivory, gamesmen shell and etched carnelian beads, all originating in the Indus valley and Gujarat found their way to Sumerian cities. Lothal had to import the raw material needed for bead-making from Bhagatrav and Mehgam, two smaller ports situated at the mouth of the Kim and Narmada rivers respectively. Timber came from

the same region or further south from the Konkan coast. Gold must have been received from Kolar, Shimoga, Dharwar and Raichur districts of Mysore State via Krishna and Godavari valleys or through one of the west coast ports, notably Honavar to which reference has been made earlier. Ivory which was available in Kathiawar was processed at Lothal and exported to the Indus valley as well as Sumer. Lothal and Indus cities received their supply of silver either from Afghanistan or the Kolar gold-bearing mines. Some scholars believe that Mohenjodaro obtained its supply of copper from the Khetri or Devbari mines in Rajasthan, but there is no evidence to show that they were worked as early as the third millennium B.C. On the other hand, import of copper ignots by Loathal from Susa or from Oman is highly probable for, the bun-shaped ingots of copper from Lothal and Susa agree in all details such as shape, weight and chemical composition (especially, absence of arsenic). It is the Dilmun merchants who, according to the Sumerian writings, brought copper to Ur, Warka and other cities in exchange for wool, oil, etc. The most coveted objects they carried were of course the glittering beads of semi-precious stones in the manufacture of which Lothal and Chanhu-daro had specialised.

A. Protohistoric Period

The Sumerian clay tablets of the time of Sargon of Akkad (2350 B.C.) mention that ships from Telmun, Makkan and Meluhha were moored outside the capital, namely Agade. During this period, Telmun or Dilmun was no more than a refuelling station. Agade and Ur had established direct trade with Makkan and Meluhha, which, according to Wheeler, lay at successively greater

distances from Ur. By 2100 B.C. there was no direct trade with Meluhha although ivory objects, gemstones, beads and copper still came from there. Under the Dynasty of Larsa (1950 B.C.). Dilmun became the principal middleman relegating Makkan and Meluhha to the background. By 1700 B.C. Dilmun lost all contact with the mining sources of Makkan. While Bibby and Wheeler are inclined to identify Telmun or Dilmun with Bahrain and Meluhha with the Indus Civilization, Kramer identifies Dilmun with the Indus valley and Kathiawar coast. The Sumerian clay tablets refer to Dilmun as the land where the Sun rises. Obviously, it must have been situated to the east of Mesopotamia. As Bahrain is situated south of it the reference may not be to this island. Furthermore Dilmun is said to be a land of clean cities, and elephants are said to have flourished there. We know for certain that Kathiawar (Saurashtra) war the habitat of elephants even as late as the 3rd cent. B.C., and undoubtedly the Indus cities were the cleanest of all. In the time of Sargon these

Fig. 3. A Royal pleasure boat 6th Century A.D. painting. Planks joined edge to edge

cities had direct trade contact with Ur, Brak and Susa. After the fall of Harappa, Mohenjodaro and Lothal in 1900 B.C. overseas trade of the Indus Civilization declined and perhaps they lost direct trade contact with Mesopotamia. Ivory, shell, gemstones and wood were exported to Ur directly between 2300 and 1900 B.C. and through the intermediary of Bahrain after 1900 B.C. In the latter part of the second millennium B.C. much of the trade with India appears to have been in the hands of the Phoenicians whom some scholars are inclined to identify with the Paṇis of the *Ṛgveda*. References to India's trade with Egypt, Puṅt, Babylon and South Arabia at the end of the second millennium and early part of the first millennium B.C. are contained in the Bible, the *Mahābhārata*, and the Buddhist *Jātakas*. Unfortunately we have little reliable information about the trade routes of the pre-Buddhist period except by way of casual references in the Bible and in the *Bāveru Jātaka*. South Indian ports appear to have played a big role in the sea-borne trade of the 1st millennium B.C. as is evident from the use of Tamil words in the Bible and early Greek texts. During the next phase however India became once again the centre of attraction for overseas trade.

B. Roman Period

This phase starts with the 1st century A.D. The commodities greatly in demand in the Roman world were spices and perfumes, precious stones such as beryl and silks, muslins and cotton which India produced in abundance. Much of the beryl, and almost the whole of peppe came from south Indian ports. Muslin was supplied by the Deccan. All these commodities were paid for in gold and silver by the Roman traders so much so that

Pliny (77 A.D.) lamented the wasteful expenditure on perfumes and personal ornaments, which drained the Roman Empire of a hundred million sesterce a year. But after the death of Nero, trade in spices and luxuries declined steeply. However the demand for muslins continued for sometime. Once again the demand for pepper increased shrply to such as extent that when Alaric spared Rome in 408 A.D. he is said to have demanded 3000 pounds of pepper. From Roman ports came gold, wine and perhaps Roman soldiers and women whose services were needed in the courts of the Chola Kings of south India.

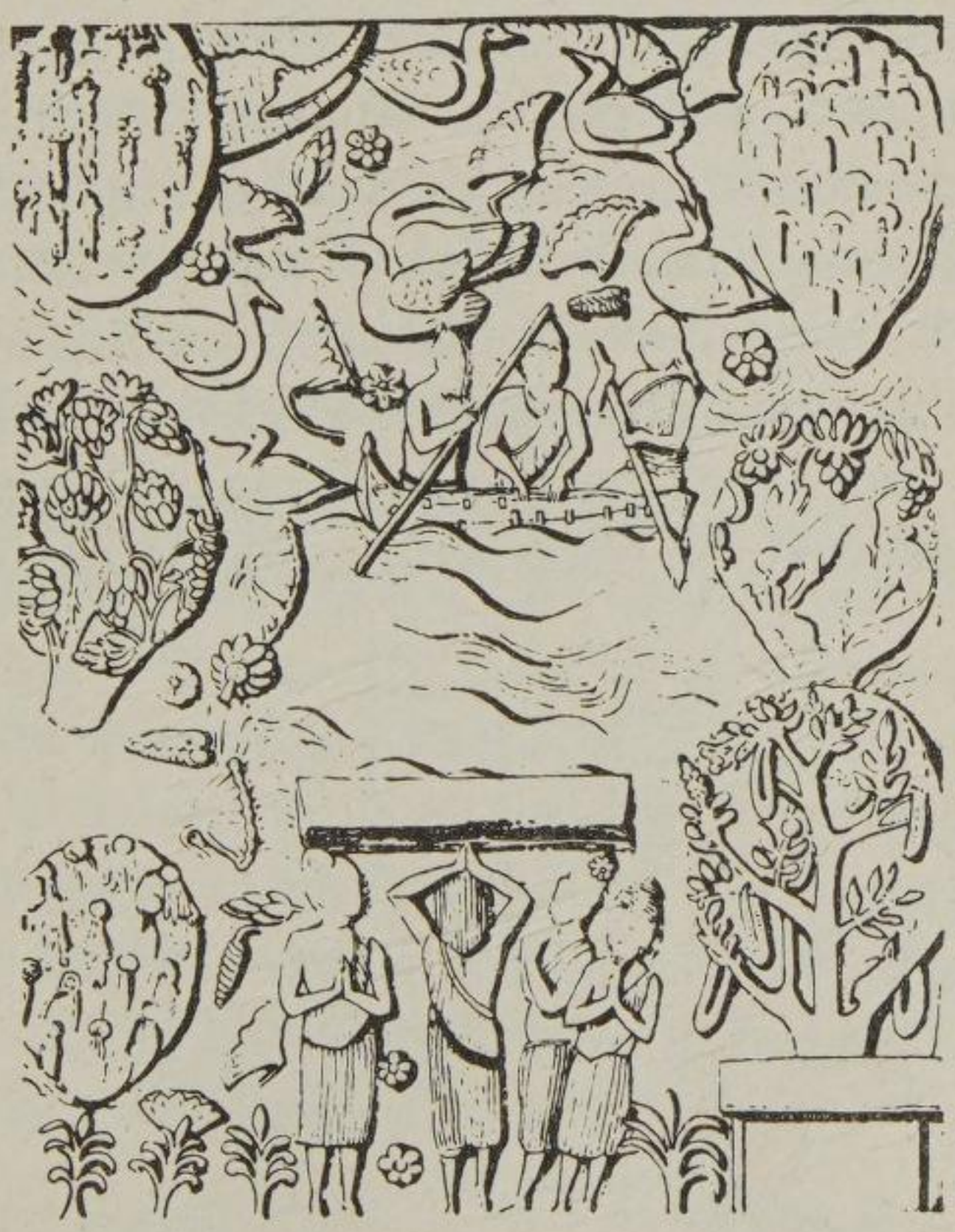

Fig. 4. Sanchi Stūpa No. 1 Sculptural representation of a boat carrying ascetics

The traditional export of India namely cotton, spices and precious stones was kept up in the Gupta and post-Gupta period too. The Deccan and Gujarat were then supplying cotton, and Malabar the spices.

We have observed in the preceding paras how Indian shipping gradually developed into a powerful instrument for spreading Indian Culture in south Asia, and also brought in much material wealth to the country. India became a great naval power to be reckoned with in the 6th-8th centuries A.D. But soon here overlordship of the Indian ocean was challenged by the rise of Islam in Arabia. There was a deep-seated jealousy among the Arabs against Indian shippers and pirates. An opportunity to reak vengeance came when a ship sent by the ruler of Ceylon to Hajjaj and the Khalifin 712 A.D. was plundered by the pirates near Debal. Soon Muhammad bin Kasim came in ships with his men and conquered Sind. In the 9th century the Arabs under the Khalif of Baghdad conquered Egypt and monopolised the trade with India. Sultan Mahmud

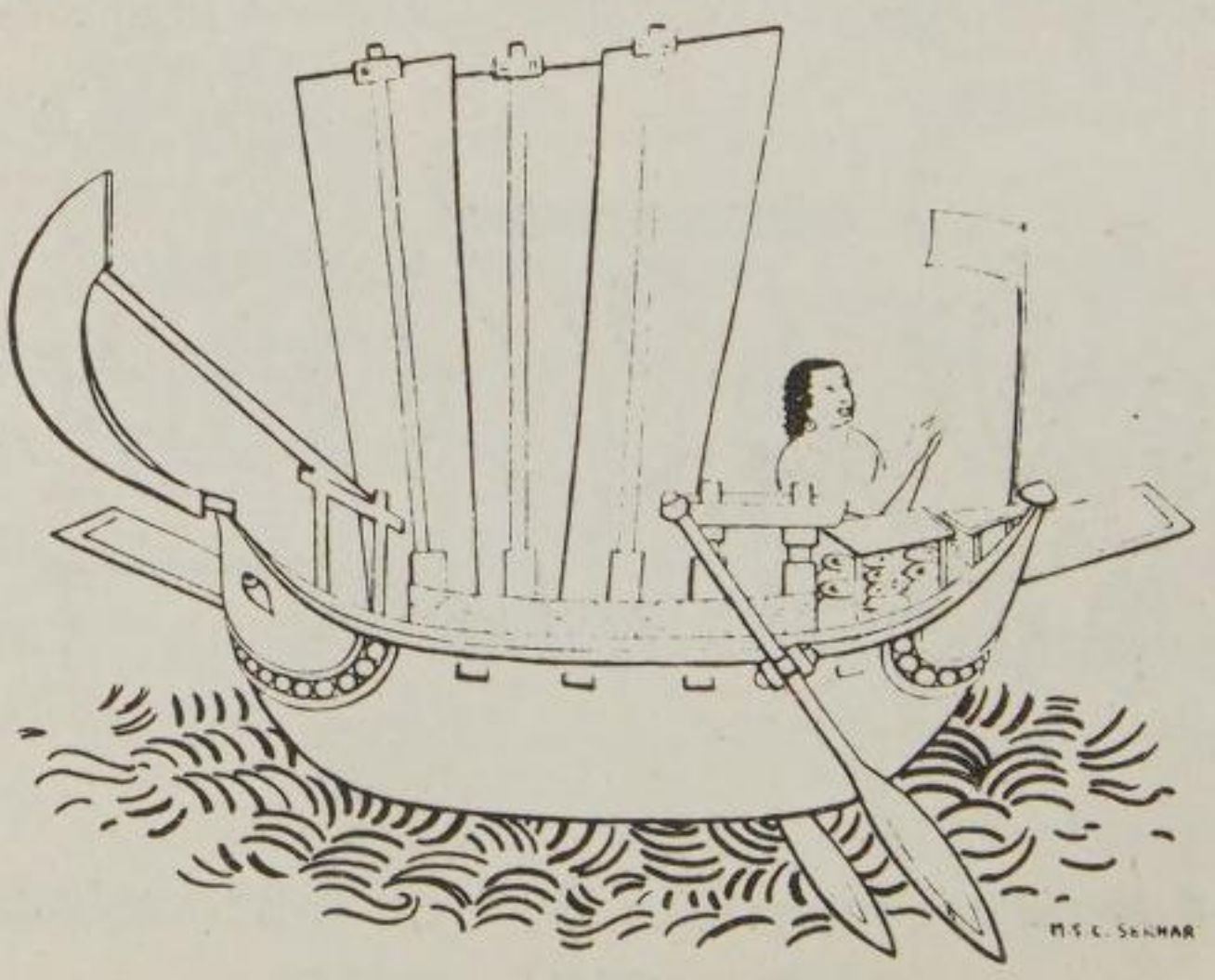

Fig. 5. A sea-going vessel (Ajanta)

Fig. 6. A multi-masted ship from India sailing for Java

attacked the boats of the Jats for having molested his force on sea. According to Ibn Batuta, Debal, Somnath, Cambay and the ports of the Malabar coast exported various commodities and extended trade upto Java. They also subdued the pirates operating near the Coromandel coast.

Among the foreign travellers who give an account of India's maritime trade in the 13th century A.D. is Marco Polo (Thomas Wright, *The Travels of Marcopolo*) who mentions the pepper of Malabar and the fine cotton of Coromandel coast. Quilon, he says, exported ginger, indigo and pepper, while Cambay was known for its cotton and leather. Marco Polo gives an account of the technique of ship-building adopted in India, as also the size and other details.

The great skill retained by the Rajput sailors in the 14th century in crossing the Indian ocean is attested by the account of Friar Odoric. According to him the ship had 700 passengers. Throughout the medieval period India

retained its supremacy in overseas trade with the eastern countries especially Burma, Java, Sumatra, Borneo, and China. It is the Sultans of Ahmadabad who were virtually the lords of the Sea in the 15th and early part of the 16th centuries. They had maintained a royal navy for protecting the merchant navy. In 1521 A.D. the admiral of the King of Gujarat defeated the Portuguese fleet near Chaul. The subsequent history of the struggle naval supermacy and conquest of India is too well known to be repeated. With the establishment of the British power in India, the indigenous ship-building industry suffered very heavily and the overseas trade came to be monopolised by the British. However, after regaining independence in 1947

Fig. 7. Sanchi: Sculptural representation of boat decorated with fanciful animals

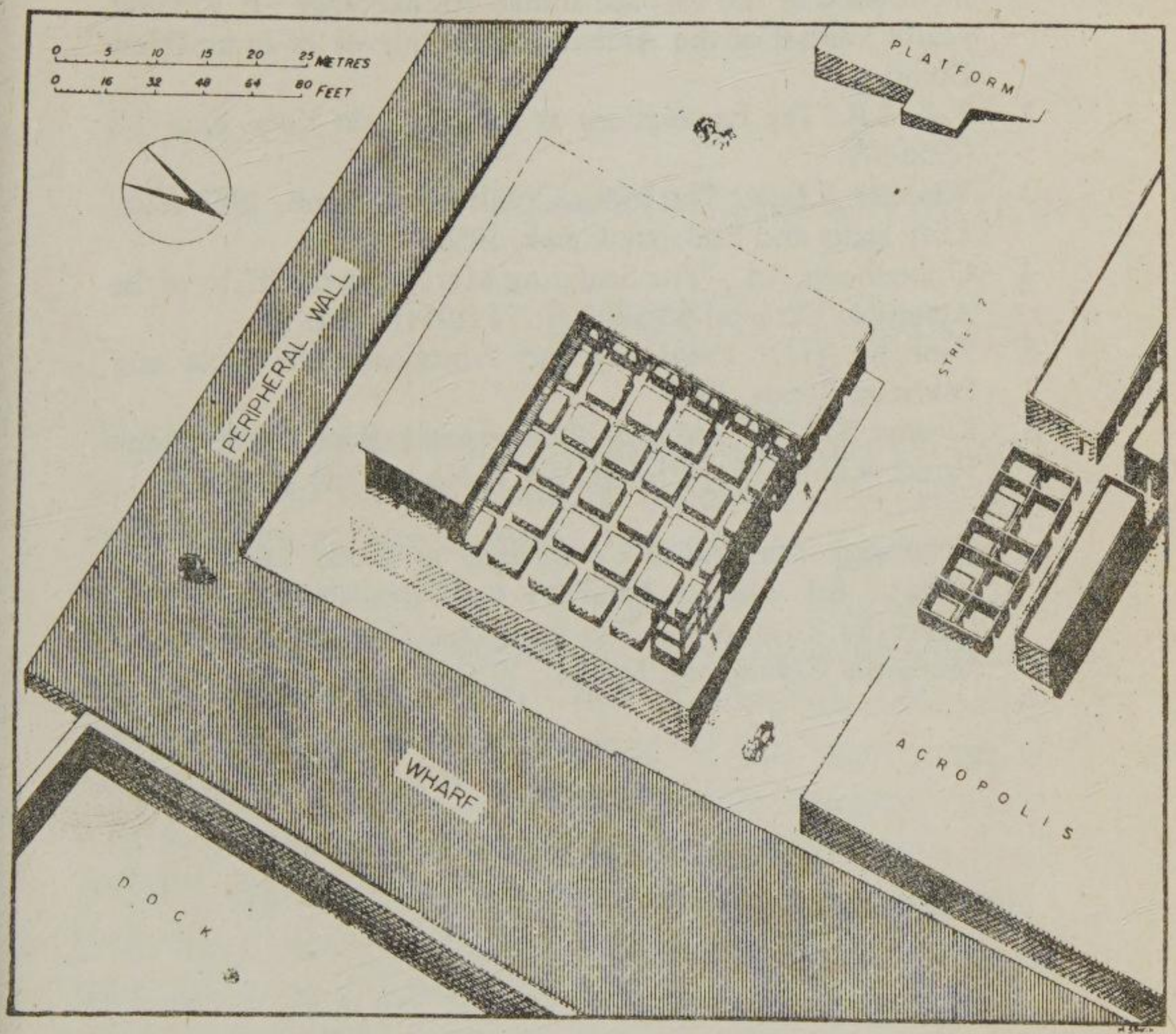

Fig. 8. Lothal: Warehouse and Environs (Axonometric View Reconstructed)

the Government of India has been making a serious effort to develop the ship-building industry with indigenous material and skill and has also been acquiring some vessels from other countries. This, in brief, is the history of one of the earliest seafring nations of the world.

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14

The Company's Marine

LATE S.M. EDWARDES

The history of the Company's Marine commences in 1613, when a squadron was formed at Surat to protect the East India Company's trade from the constant aggressions of the Portuguese and the pirates who infested the west coast of India. Included in this squadron were the *Dragon* and *Osiander*, commanded by Captain Best, who ultimately broke the marine predominance of the Portuguese at Swally in January, 1615. At that date the Company's naval forces comprised these two English ships and ten armed *grabs* or *gallivats*,[1] which may be held to have formed the original nucleus of the Bombay Marine. This small force gradually increased during the first half of the seventeenth century, and during that period was engaged in a practically continuous and on the whole successful struggle with the Company's adversaries in India. In 1669, after the transfer of Bombay to the Company, a further development took place; the construction of small armed craft at Bombay, for the protection of the Persian Gulf and Arabian Sea trade, was commenced, among them being two brigantines built by a descendant of the Elizabethan shipwright, Phineas

Pett; and in 1686 the whole marine establishment was finally transferred from Surat to Bombay, the marine stores being housed in Bombay castle and the ships anchored in Bombay harbour. After this date the Company's sea-forces were officially styled the Bombay Marine; an officer was regularly appointed "Admiral" every year; while a supply of men for both upper and lower decks was maintained as far as possible by drafts from England. The Marine suffered to some extent from the lawlessness and insubordination which marked the end of the seventeenth and the early years of the eighteenth centuries. Two vessels, the *Revenge* and *Hunter*, played an active part in Keigwin's rebellion of 1683;[2] disease and financial embarrassment were responsible for reductions of the strength of the force; while desertion was so frequent that in 1724 it was decided to keep the pay of all seamen two months in arrears.

In 1716 the Marine comprised one ship of 32 guns, four *grabs* with 20 to 28 guns, and twenty smaller *grabs* and *gallivats*, carrying 5 to 12 guns apiece. This force made an unsuccessful attempt to seize Gheria (Vijayadrug), the stronghold of Angria, in 1717; and in the following year made a fruitless attack upon Kenery (Khanderi) island, under the command of Manuel de Castro, whom the president, Charles Boone, much to the annoyance of the English personnel, had appointed Admiral of the Fleet for the occasion. Co-operation with the Portuguese seemed fated to end in disaster, for in 1722 a joint expedition by the Bombay Marine and a Portuguese land force against the fort of Alibag was badly defeated, owing largely to the mistakes and malingering of the Portuguese viceroy and his general and the poor quality of the Bombay troops.

Commodore Mathews of the English Navy participated in this action with four English ships, which had been dispatched by the Home Government in 1721 to assist in clearing the Eastern seas of European pirates. A contemporary writer gives an amusing description of Mathews's choleric treatment of the Portuguese authorities after the failure of the expedition[3] of which the only creditable feature was the bravery displayed by the officers and seamen of the Company's Marine. During the first three decades of the eighteenth century the antagonism of the Portuguese, the Marathas, and the Sidi of Janjira obliged the Bombay Council to improve the strength and status of the Marine; a pension scheme for the widows of officers and seamen was instituted; several new vessels were purchased; and the crews of the Company's trading vessels were freely borrowed for the manning of their warships. Consequently by 1735 the annual expenditure on the Marine had increased to nearly two lakhs of rupees, and the fleet comprised seven large warships and a variety of *gallivats* and smaller vessels.[4]

From the earliest years of the Company's possession of Bombay, a marine establishment ashore, distinct from the force afloat, was maintained under the direction of the Commodore of the Marine, and included, among other officials, a storekeeper, a paymaster and a purser marine. The last-named was concerned with supplies of all kinds to the ships and indented for their cost by a monthly bill on the paymaster, who had "the charge and direction of watering and ballasting the Company's vessels and of purchasing what timber and coir were wanted for their service". An important step was taken in 1735, when the Bombay Council decided to transfer their shipbuilding

yard from Surat to Bombay, and brought thither with it Lavji Nasarvanji Wadia, the Parsi shipbuilder, who had been foreman of the Surat yard. His first duty was to select a site for a dockyard, the only dock available at the date being a mud basin, which filled and emptied with the tide. The first dock, constructed on the site chosen by Lavji, and known to-day as the Upper Old Bombay Dock, was eventually opened in 1754. A second dock, the Middle Old Bombay Dock, was completed in 1762; and a third, the Lower Old Bombay Dock, in 1765. For the next forty years these three docks were the boast of Bombay and the wonder of travellers like Grose (1750), Ives (1758) and Parsons (1775). Lavji Nasarvanji, who served as master builder from 1735 to 1774 and was succeeded in office by his two grandsons, made continual additions to the Bombay's fleet, and the reputation for strength and seaworthiness of the teakwood ships built by him and his grandsons was so widespread and so well deserved that the office of master-builder remained in the hands of the Wadia family until 1885, when the work of construction and repair was entrusted to an English chief constructor, trained in the royal dockyards, with a staff of European assistants. The most notable member of the family was Jamshedji Bomanji, who between 1793 and 1821, built several line-of-battle ships and frigates for the Royal Navy, besides war vessels and other craft for the East India Company. During his tenure of office he witnessed the completion in 1807 of a fourth dock, the Upper Duncan Dock, and the construction in 1810 of an outer or repairing dock, the Lower Duncan Dock, both of which were named after Jonathan Duncan, who was governor of Bombay from 1795 to 1811.[5]

Meanwhile the Marine, which in 1740 comprised a hundred officers and about two thousand seamen, who were chiefly English but occasionally deserters of other European nations, had commenced to lay the foundation of its subsequent reputation. In December, 1738, Commodore Bagwell, in command of four cruisers, heavily defeated Sambhaji Angria's fleet at the mouth of the Rajapur river;[6] in 1739, after the fall of Bassein, Captain Inchbird of the Marine negotiated a treaty with the Marathas;[7] and in 1756 a fleet of ten ships, under the command of Commodore James, co-operated with a royal squadron under Vice-Admiral Watson and a military force under Clive in a second attack upon Angria's fort of Gheria. The operations on this occasion were wholly successful; the fort was captured on 13 February, 1756; and the piratical chief of the Konkan ceased from that date to figure in the politics of Western India.[8] On the outbreak of the Seven Years' War, Commodore James (who subsequently became governor of Greenwich Hospital) added to his reputation by capturing a French vessel in 1756 and carrying her as prize to Bombay, and by voyaging round the coast of India in the height of the south-west monsoon, with the object of proving that communication between the eastern and western coasts of India was possible at all seasons.[9] This feat of navigation, which enlarged the views of the authorities as to the potential value of the Marine, proved doubly advantageous to the English; for the commodore not only brought to Bengal the earliest news of the outbreak of war with France, but also lent the services of five hundred of his seamen to Watson and Clive, for their attack on Chandernagore in March, 1757.[10] During the struggle between France and

Council, who were expected merely to exercise general supervision over the various officers of Marine and secure obedience to the policy of the directors, while all executive orders relating to daily marine and dockyard administration were issued by the governor in council.

The valuable service rendered by the Bombay Marine during the second half of the eighteenth century was largely responsible for a revision of the Marine Regulations by the court of directors in 1798. Relative rank and retiring pensions were conferred upon the officers of the service, and the privilege of private trading, which had till then been allowed to all members, was formally abolished. The duties of the Marine were now defined to be (a) protection of trade, (b) suppression of piracy and general war-service. (c) convoy of transports and conveyance of troops, (d) marine surveying in Eastern waters. A Marine Board was established, composed of a civilian superintendent as president, a master attendant, a commodore and two captains, these four appointments being reserved for the four senior officers of the Marine. The remaining personnel at this date consisted of thirteen captains, thirty-three first lieutenants, twenty-one second lieutenants and thirty-seven volunteers. The regulations of 1798 were amended by the issue in 1814 of a warrant of precedence in India, by the publication in 1820 of new regulations as to uniform, and by the temporary abolition of the rank of commander and the provision of additional captains' appointments in 1824. Later on, in 1827, a royal warrant was issued, conferring upon Marine officers equal rank, according to their degrees, with officers of the Royal Navy, within the limits of the East India Company's charter; by the issue of an Admiralty warrant empowering

Bombay Marine ships to fly the Union Jack and pennant; and thirdly by an order that the appointment of superintendent, as head of the Marine Service, should in future be held by an officer of the Royal Navy. Finally, in 1830, the title of the service, which included at that date twelve captains, nine commanders, fifty-one lieutenants and sixty-nine midshipmen, was altered to that of "the Indian Navy".[16]

The principal administrative changes after that date consisted in the appointment in 1831 of a Controller of the Dockyard in supersession of the master attendant, the institution in 1838-9 as an integral branch of the Marine of a steam-packet service for the carriage of mails to Egypt; the gradual substitution of steamers for the old teak sailing vessels;[17] and successive alterations in the numbers of the service, which was officially declared in 1847 to consist of eight captains, sixteen commanders, sixty-eight lieutenants, 110 midshipmen, fourteen pursers and twelve clerks, fourteen masters and twenty-one second masters. The post of Superintendent of Marine disappeared in 1848, the holder at that date being styled Commander-in-Chief of the Indian Navy; and the broad pennant of the Indian Navy, which had till then been identical with that of the Royal Navy, was superseded by a red flag with a yellow cross and East India Company's cognisance of a yellow lion and crown in the upper corner nearest the mast. On the assumption by the crown in 1858 of direct rule in India, the title of the Indian Navy was changed to that of Her Majesty's Indian Navy; and in the following year the duties of the Controller of the Dockyard, which also included the administration of the port and other duties now performed by the Bombay Port Trust, were limited to

the commercial work of the port, while his dockyard duties were transferred to a dockmaster, now known as the staff officer. In 1863 a new code of regulations was issued; the name of the service was once again changed to the Bombay Marine; and the recruitment of European seamen was prohibited, their places being taken by Indians belonging to the seafaring classes of the western coast—descendants, in fact, of the coast pirates with whom the Marine waged so fierce a struggle in the seventeenth and eighteenth centuries.

The war services of the Bombay Marine continued during the first half of the nineteenth century. It shared in the Egyptian campaign of 1801, helped to guard the Bay of Bengal from French aggression in 1803, assisted at the capture of Mauritius in 1810, and participated in the conquest of Java in 1811. In 1813 it was employed against the Sultan of Sambar; in 1815 it blockaded the piratical strongholds of Cutch and Kathiawar; it assisted in the attack on Suvarndrug and Madangadh during the third Maratha War; and it practically exterminated piracy in the Persian Gulf in 1819.[18] The siege and capture of Mocha in 1820 offered the opportunity for a fresh display of prowess on the part of the Marine;[19] in the following year four ships under Captain Hardy, Commander Stout and Lieutenants Dominicetti and Robinson reduced the Ben-ibu-Ali Arabs to submission; and in 1826 Commodore Hayes and other officers of the Marine received the thanks of parliament for their "skilful, gallant and meritorious exertions" against Ava. Between 1830 and 1863 the Indian Navy was on practically continuous service in India and the Persian Gulf. The power of the

Beni-yas Arabs was broken by Captain Sawyer of the *Elphinstone* in 1835; in 1838 the Indian Navy provided a blockading squadron at the mouth of the Indus; it served under Admiral Maitland in the Persian Gulf and at the capture of Aden in 1839: it co-operated with the Royal Navy during the China War of 1840-2; the officers and crews of three vessels under Commander Nott fought at Miani and Hyderabad (Sind) in 1843. The Company's vessels carried troops to Vingurla during the insurrection of 1844-5 in the Southern Maratha country; in 1846 the *Elphinstone* (Captain Young) shared in the capture of Ruapetapeka (New Zealand); during the siege of Multan in 1848-9 the Indus flotilla was provided by the Indian Navy; it vessels captured Bet island in 1850, played an important part in the second Burma War of 1852, suppressed piracy on the north-east coast of Borneo in the same year, and helped the Turks to defend Hodeida in 1856.

On the outbreak of war with Persia in 1855, the sea forces were drawn entirely from the Indian Navy, with Rear-Admiral Leeke in command and Commodore Ethersay of the Company's service as second. Bushire was taken in 1855 and Muhammarah in 1857—the latter operation, which had to be carried out under great difficulties, evoking from the governor-general in council a well-merited eulogy on the judgment, skill and discipline shown by all ranks. The Indian Navy distinguished itself during the military operations in South China and at the seizure of Perim island in 1857; it provided naval brigades for service ashore during the Mutiny, while Captain Jones of the Indian Navy held the Arab tribes of the Persian Gulf at bay during the same grave crisis. The tale of the active

war services of the Bombay Marine forces ends with the China War of 1860, when the attack on the Taku forts was led by the *Coromandel*, commanded by Lieutenant Walker.

The organisation of the Indian trooping service in 1867 sounded the knell of the Indian Navy as a fighting force. The officers' cadre was then enlarged to include twelve commanders, ten first, eleven second, and seven third officers, and 109 engineers. One resident transport officer was appointed from the service. Ten years later (1877), however, in consultation with Captain (afterwards Admiral) By the sea, the Indian Government effected a radical reorganisation of their naval establishment. The Bombay service was amalgamated with other marine establishments in India, under the title of Her Majesty's Indian Marine, the combined establishments being divided into a western division concentrated at Bombay and an eastern division at Calcutta; and the duties of the service were declared to be (a) transport of troops and government stores, (b) maintenance of station ships in Burma, the Andamans, Aden, and the Persian Gulf for political, police lighting and other purposes, (c) maintenance of gunboats on the Irawadi and Euphrates, (d) building, repairing, manning and general supervision of all local government vessels and launches and all craft used for military purposes. In 1878 a naval constructor was appointed from England for the first time, and this was the prelude to the retirement in 1885 of the last of the Wadias, whose connection with the dockyard as master-builders had lasted without a break for one hundred and fifty years. In 1882 the appointments of Superintendent of Marine at Bombay and Calcutta, which were included in the reorganisation scheme of 1877. were abolished in favour of a single

appointment of director, to be held always by an officer of the Royal Navy with Bombay as his headquarters, assisted by a deputy, chosen from the Indian Marine and stationed at Calcutta. The anomalous position of the officers and crews of the Marine, who were not subject to the provisions of the Naval Discipline Act, and Merchant Shipping Act, was regulated by the passing of the Indian Marine Service Act, 1884 (47 & 48 Vict. c. 38), which enabled the governor-general in council to legislate for the maintenance of discipline and simultaneously the post of assistant secretary to the Government of India (Marine Department), which had been created in 1880 and held by Admiral Bythesea, was replaced by that of assistant director of the Indian Marine. An admiralty warrant of the same year (1884) sanctioned the use by ships of the Indian Marine as ensign of a blue flag with the Star of India in the fly, and as marine jack of a union jack with a narrow blue border. Finally in 1891 the title of the service was once more altered to that of "The Royal Indian Marine" by an order in council, which also provided that officers of the service, with the titles of commander, lieutenant and sublieutenant, should rank with, but junior to, officers of the Royal Navy of equal rank, and should wear the same uniform as the latter, with the exception of the device on epaulettes, sword-hilt, badges and buttons, and of the gold lace on the sleeves.

This retrospect may fitly conclude with a brief notice of the Naval Defence Squadron and of the later progress of the Indian Marine Survey. The former which was established at Bombay in 1871 for the defence of the Indian coasts, consisted in 1889 of two turret-ships and seven torpedo boats, commanded by officers and manned

by crews of the Indian Marine. In 1892 the squadron, which had been increased by the purchase of two torpedo gunboats, was placed under the command of an officer of the Royal Navy, while the other officers were chosen partly from the Royal Navy and partly from the Royal Indian Marine. The crews comprised both bluejackets and lascars. In 1903 the squadron was abolished, and the defence of India by sea was entrusted wholly to the Royal Navy.

The history of the survey during the nineteenth century opens with the establishment in 1809 of a Marine Survey department in Bengal, which charted the east coast of Africa as far south as Zanzibar, the Persian Gulf and other seas, before it was abolished in 1828 during Lord William Bentinck's administration. The work of the department, however, was considered sufficiently important to be carried on between 1828 and 1839 by two vessels, which explored the coasts of Africa and Socotra, the Maldive and Laccadive islands, and the mouth of the Indus. After 1844 comprehensive surveys were conducted on the Jehlam and Indus rivers, in the Gulf of the Cutch and other parts of the west coast of India, in the Bay of Bengal, on the Pegu coast and the rivers of Burma, and in Malacca and Sumatra. In 1861 the control of the Indian Marine Survey was transferred to the Admiralty, but seventeen years later (1878) it was again organised in Calcutta as a department of the Indian Marine. The headquarters were transferred from Calcutta to Bombay in 1882, and a year later it was decided to reserve the appointments of surveyor in charge and his senior assistants for officers of the Royal Navy and to fill the junior officers' grades from the Royal Indian Marine. From 1894 the senior assistants'

appointments were also thrown open to the latter service. Since its first establishment the Royal Indian Marine has performed much valuable work in the charting and delineation of the coasts of India, Burma, the Persian Gulf and Africa, besides materially advancing scientific knowledge of the funa of the Indian seas.

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The other important topics are the Aspects of Metal Technology during the early Historic period and the history of Iron and Steel-making in India. Origins and Developrnent of Iron in India and Copper Bronze Technology have been mentioned in detail.

The Glass-making in ancient and medieval India, Indigo Industry in India, Evolution of Industries and Industrialization in Primordial Tamil Nadu too are very important aspects which have been described.

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The book will be of great value to readers especially the students because it has wide range of information regarding science and its various ramifications. The erudite scholars who have contributed their articles in this book have vividly depicted authentic and useful information for the study of scientific developments of India.

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